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TEXAS

The annual meeting of the Society for the Promotion of Engineering Education at College Station this coming June offers a singular appeal to the members of the Society to visit a State rich in romance and history, and at the same time a State that is enjoying an economic expansion not current in any other State in the Union. Texas, if not the last, is one of the few remaining economic frontiers in the United States. Because it is rich in all types of natural resources, agricultural productivity, and just beginning to enjoy a tremendous industrial expansion, the opportunity of seeing this State ought to carry an irresistible appeal to our engineering group.

Within the borders of Texas, which State's traditional immensity is known to every school boy, are to be found every type of climate, every type of mineral deposit, every type of agricultural productivity, and almost every type of soil and physical make-up that are to be found in all of the other States of the Union. It may be snowing in Amarillo on the same day that there will be Gulf bathing in Galveston. The Rio Grande Valley is famous for its citrus fruits, the Fort Davis Mountain region for its apples, and scattered throughout the State is to be found nearly every fruit that grows on the American continent.

The Agricultural and Mechanical College of Texas is situated not far from the center of the State. One hundred and fifty miles to the south is the great coastal area, with wonderful fishing grounds and fishing industries. To the east and southeast are the great timbered regions, where vast areas of native pine are transformed into building materials. A few hundred miles to the southwest is the magical Rio Grande Valley, home of the great vegetable and fruit canning pursuits. To the north lie the rolling blackland prairies, where cotton, corn, wheat and oats are grown. Both in the coastal area and to the west and northwest are the great cattle ranges. Petroleum is found in almost every county in the State, with the great East Texas oil field the world's largest, only 120 miles removed from the College.

San Antonio, with the atmosphere of Old Mexico, is nearby. Fort Worth, the cowtown, is to the northwest, Dallas, the great commercial center, to the northeast, while Houston, the State's largest city, the world's oil capitol, and second largest seaport in the United States, is only ninety-five miles south of College Sta-

tion. All of the industries that usually would be scattered throughout a great area with vast distances between them are huddled together in close proximity in Texas. Lumber, rice, petroleum, sugar, sulphur, cotton, fruits and vegetables, all of these are produced on a great commercial scale.

Come to the State which has maintained its integrity and independence under six flags. A State where the Gulf breezes make the evenings delightful. See it in all of its variety and immensity. No State in the Union offers an opportunity to a young man comparable to that which is to be found here in Texas. An excellent system of State highways makes all points of the State easily accessible. If you do not like the coastal prairie, a few hours' drive and you are in the Fort Davis Mountains, with an elevation in excess of eight thousand feet. A hearty welcome awaits all of the members of the S. P. E. E.

A. S. M. E. MEETING

The American Society of Mechanical Engineers will hold its semi-annual meeting in St. Louis, Mo., during the week of June 20–24, 1938. The headquarters will be at the Statler Hotel.

An innovation this year will be "the conference of professional and technical committees to be held during the Annual Meeting when contacts can be made with the Council and the Group Delegates Conference."

This meeting is being held the week previous to the 46th annual meeting of the Society for the Promotion of Engineering Education at the A. & M. College of Texas, College Station, June 27–30. It is the hope that many members of both societies will take advantage of this arrangement and attend both meetings.

REACTION OF AN ENGINEERING EDUCATOR TO PERTINENT CRITICISMS OF ENGINEERING EDUCATION FROM INDUSTRIALISTS

By F. W. ROYS

Head, Department of Mechanical Engineering,
Worcester Polytechnic Institute

Mr. W. H. Carrier and Mr. N. E. Funk have written rather pertinent criticisms of the accomplishments of Engineering Education. In these two papers, which appear in the May issue of *Mechanical Engineering*, the organ of the A. S. M. E., we find statements to the effect that

(*a*) The present system, instead of stimulating the creative imagination so necessary to the successful engineer, seems to discourage or dull it.

(*b*) Students form the habit of accepting facts blindly and memorize them instead of learning to reason for themselves and really understand the fundamentals of their subjects.

(*c*) Engineering students have a superficial knowledge of many things; minds loaded with partly digested facts but poor grounding in basic physical laws.

(*d*) Valuable time is list by needless repetition: theory of impression by repetition granted but students do not profit.

(*e*) Mathematics taught as mental exercise is largely memory. Too much time is spent on algebraic juggling and tricky solutions, which few will ever use in engineering practice, and too little time on developing a real understanding of fundamental philosophy of method.

(*f*) The deductive method, which has many advantages in way of orderliness, comprehensiveness, ease of correlation, ease in learning, and ease of administration, is not the natural way, but the inductive method of going from the concrete to the abstract is more natural and, although slower and harder to administer, productive of better results in the long run.

(*g*) There should be better correlation between scientific thought and practical application.

It is the purpose of this paper to discuss these seven points from an educator's point of view, by one who appreciates fully the conditions which have drawn out the criticisms noted above.

In regard to (*a*), *i.e.* stimulating of the creative imagination necessary to the successful engineer, etc. If anyone not familiar with engineering education could see the raw material upon which we have to work he would realize that these boys who come to us as freshmen are on the whole almost totally without background. Most of them have had no real practical experience. Fifty years ago many of the boys came from rural sections or small commercial centers where they had had opportunity to work on the farm or in a general shop. They learned by force of circumstance to be resourceful and self-reliant. Necessity forced them to work out their own salvations or go without. Those days are gone and we cannot get them back. It is rare indeed to find a boy who has had an opportunity of that kind. Even in those days when engineering had not advanced very far, training in the practical background was considered essential. Nowadays, however, when the pre-college days afford less opportunity for establishment of this background, the college curriculum in general has also tended to cut the time allotted to this type of work. Take this situation along with the fact that there has been an increasing demand for cultural work along literary, economic and sociological lines and consider what the colleges are up against in trying to compensate for the changed conditions over which they have no control.

Some colleges, where the mathematical, pure science approach is traditional and where shops, laboratories and practical facilities are inadequate, discount the value of such things, but others who have the facilities and who have men experienced in the requirements of engineering are doggedly persisting in building into the training of young men this practical kind of background. On every technical college faculty there are those who, having had no practical commercial experience, do not appreciate its value and actually have no patience with the other point of view. The pressure put on students in order to build something of a background often seems to discourage initiative, but if they have the ability to profit by their opportunity, then they are able to use their imaginations in creative work. Industry is becoming alive to this situation and is showing more interest in practical curricula and in the high-grade men who graduate from schools which have such curricula.

In regard to (*b*), namely that students form the habit of accepting facts blindly instead of learning the reason, etc. There can be no question that this criticism is well founded. The situation arises largely from the fact that in science and mathematics the demand for acquaintance with developments of science and applications of mathematics to special reductions has far overrun the time available for such subjects in the undergraduate curriculum. Also,

since the scope of these subjects is so great and the time so short, they must be handled from the deductive standpoint. This requires a statement of general principles which must be accepted by students if they are to carry on. They have no alternative. They have to memorize equations, laws and methods in order to get underway at all in the time available. They learn how but not much of why. However, let us be sure that the *worthwhile students* do not accept these things blindly; they have plenty of mental reservations and later on when applications in practical subjects occur, these reservations crop up in countless questions. The poorer students who have little aptitude never come to the surface and of course they suffer most from this forced method of instruction.

Let no one get the idea that the really good man is at much of a disadvantage on this score, especially in schools where the junior and senior work is progressively handled more from the inductive or natural standpoint.

In regard to (*c*), that engineering students have a superficial knowledge of many things; loaded with partly digested facts but poor grounding in basic physical laws. On the first of these items there is no argument. A great deal of the work has to be informational. However if the uninitiated could know of the pressure from various sources to include a little instruction in each of a multitude of specialties, they would realize that a careful study has to be made to know what to include and what to exclude. They would know that the locality of the college and the industrial or commercial enterprises into which the college feeds its graduates have a great deal to do with the selection of such material; they would know that partly digested facts have to form a part of the student's equipment in order to establish a horizon for him. Later on he will fill in more or less between his well-worn stamping ground and his distant horizon, but no one ever fills it all in. Of course we expect some field to be cultivated to bear good fruit and plenty of it, but he would be a poor man who didn't have a store of more or less superficial acquaintance with allied subjects outside his own particular field. We do not need to be too apprehensive about this particular criticism.

In regard to (*d*), valuable time lost by needless repetition, the argument is that students do not profit by the opportunity to improve by repetition. In the institution with which I am most familiar it is well established that there is considerable repetition. Not so much direct repetition as repetition by various applications of the same principles. It is this recurrence of fundamentals in seemingly disassociated subjects that finally establishes the consciousness of the importance of the fundamentals. This kind of

repetition is invaluable and staff members should co-operate most whole-heartedly to see that their methods of attack work smoothly together rather than in conflict. The co-ordination of teaching methods leads to advance, whereas conflicting methods lead to confusion. Actual, needless repetition is, of course, waste and should be eliminated.

In regard to (*e*), mathematics taught as a mental exercise largely memory, etc. It is unfortunately the impression of many engineering educators as well as practising engineers that this is the case. The writer heard this idea stated repeatedly at the spring 1937 meeting of the S. P. E. E. in Cambridge, Mass., and only recently a statement appeared somewhere that technical college curricula seemed to be arranged on the supposition that all the graduates were going into research work. The writer cannot agree that this statement will stand against investigation, but there is, nevertheless, enough evidence to show that many educators do lean heavily toward this point of view as a sort of ideal type of education for technical students.

Very likely most teachers of ordinary fundamental technical subjects such as mechanics, hydraulics, thermodynamics, and elements of electrical engineering, as well as some of the more advanced work in elementary machine design or structural design, will say that they find students able to manipulate mathematical equations of considerable difficulty, but with little ability to set up equations expressing even simple relations in technical data. The writer has heard competent mathematics teachers state that they are forced to administer their courses largely on a memory basis in order to cover the ground demanded by the technical departments. On the other hand, he has heard, many times, designing engineers of considerable standing say that the value, for the ordinary engineering graduate, of being able to handle complicated integrals or differentiation of complicated expressions is very much overstressed. It is very much more important that the emphasis be put on real understanding of elementary, simple principles than to overstress practice in complicated solutions. If there are ten per cent of the students who want to go into technical research or engineering physics, provision should be made to extend their opportunity for mathematical training at a time later in their college course when they have the background to appreciate and profit by the more advanced theory and application.

In regard to (*f*), that the inductive method is in the long run a better method for training of engineers than is the more prevalent deductive method. A sharp division of opinion will doubtless occur here. Some schools which have small endowments and which cannot obtain or maintain adequate equipment for experimental and

practical training will tend to minimize the value of the inductive method. Especially is this so where those in charge of instruction have grown up under the deductive method and have little or no practical experience either in or out of industry.

On the other hand, colleges which have adequate facilities in laboratories and shops and which have staff members with an adequate practical background are using this inductive method of teaching as much as is possible. Just how much is possible depends on many factors not ordinarily under *one* man's control. The writer knows of only one school of any standing where one man has complete control, and he is accomplishing some unique results.

There is no doubt in the mind of the writer that a good practical background gained by inductive methods is indispensable in establishing the foundation for engineering training, and so far as he is able he is directing his efforts in this direction.

In regard to (*g*), that there should be better correlation between scientific thought and practical application. It is to be supposed that this has to do with the seeming gulf between science and engineering in technical college courses. There can be no doubt that this is at least partly true but not entirely so. The writer's experience would tend to show that, while some science teachers in technical colleges are the pure science type, others are surprisingly practical and well aware of engineering applications, and the manner of instruction depends upon which of these types a student has in class. Further than that, it is generally impossible to maintain a staff of experienced men large enough to handle all the student instruction and where young, inexperienced men act as teachers in scientific subjects their knowledge of practical application is apt to be limited.

During the last few years certain engineering educators who are fundamentally research men have introduced a strongly deductive approach in their teaching. They have offered the development of highly theoretical general equations as the basis of attack for certain fundamental subjects; the idea being that from these general treatments all the simpler special cases may be deduced. From the standpoint of logical development for experienced scientific students, whose fundamental philosophy is firmly established, this may be, and doubtless is, quite satisfactory and desirable. However, such a plan of attack is very nearly ruinous for an inexperienced young student whose philosophy is still in a fragmentary if not chaotic state. The natural way is of course to take simple, special cases, find one and then another so that the learner may gradually become aware of the underlying philosophy of the subject. Then, by comparison and association, he sees the relation between the special cases, and finally he sees how the general case may be de-

veloped and how, by introducing limitations in definite ways, expressions for special cases are obtained. Research in science and engineering has been moving so rapidly during the last twenty-five or thirty years that it is no wonder that some difficulty in way of correlation has arisen. Students are being pushed to the limit tc make them seemingly more proficient in handling advanced technique. This pace, which is becoming faster and faster, is putting a terrific strain on young men who try to keep at the top. It must end somewhere for many young men will crack under the strain.

Besides this we would do well to give pause for a moment and consider the danger of discouraging the slower reflective thinker by this forced rate to meet a quick competition. There have been many of this slower reflective type who have contributed very greatly to the sum total of scientific and technical progress. Technical colleges are aware of this situation and some are deliberately interested only in the very able student who can definitely be trained for scientific or high-grade technical research. Others who are just as well aware of the situation are setting out to adapt the requirements of their curricula to a more general type of technical training, designed to fit men for general engineering activity. Engineering education is in a period of flux where types of courses are changing rather rapidly. Some of these schemes are good and some have already been found unworkable, but engineering educators are, by and large, just as interested as anyone in securing the best results with the methods and developments available, and we may be sure that in general the most effective of the newer methods of presentation will be linked with the most effective of traditional methods for a more efficient training of engineering students. Engineering education is under close scrutiny. It is being forced to clean house. Some are not going to like it, but it is being done, and we thank such interested people as Mr. Carrier and Mr. Funk for their candid criticism. The more constructive criticism we can get from those who absorb the product of technical colleges, the better able we shall be to frame our courses most effectively.

METHODS OF EFFECTING BETTER COÖRDINATION BETWEEN MATHEMATICS AND TECHNICAL ENGINEERING COURSES *

By WILLIAM C. KRATHWOHL

Professor of Mathematics, Armour Institute of Technology

A discussion of methods to effect better coördination between mathematics and technical engineering courses is always a timely one. There is no question as to whether there should be coördination. The question that concerns every member of the teaching staff is how such coördination can be achieved most thoroughly and most efficiently. This question can be handled from three sides. (*A*) How mutual help can be secured. (*B*) How mathematicians can help engineers. (*C*) How engineers can help mathematicians.

(*A*) How Mutual Help Can Be Secured

1. *There should be a division of labor in the teaching of computation.* Various methods of computation which engineers employ are arithmetic, logarithms, tables, slide rules, nomograms and calculating machines. Mathematicians should teach the first three, engineers should teach the use of the slide rule, and both should teach nomograms and the use of calculating machines.

An engineer must be able to use arithmetic. He cannot afford to travel around the country followed by a truck containing slide rules, tables and computing machines. He must be able to compute without these aids.

The mathematics department comes in contact with students not long after they have completed arithmetic. Mathematicians should be able to teach arithmetic better than engineers. This can best be done in the first part of the course in trigonometry before logarithms are reached. It also can be done by insisting that whenever a problem arises which requires a numerical solution, that the solution either be carried out to a specified number of decimal places, or be left in the form of a common fraction reduced to its lowest terms.

Emphasis in teaching arithmetic should be put on the following topics, (1) general short cuts in arithmetic, (2) quick and easy

* Presented at the Spring meeting of the Illinois-Indiana Section, S. P. E. E., April 3, 1937.

ways of checking a solution, (3) modern methods of performing subtraction, division and multiplication, (4) the application of algebra to arithmetic.

Mathematicians should teach thoroughly the theory of logarithms. If this is done, slide rule manipulation comes easy. Emphasis should be put on problems of the type $0.234^{7.167}$.

Since problems occasionally occur in engineering that cannot be done with a slide rule which is shorter than a telegraph pole, a student should be able to use accurately and to its limit a table of logarithms of 5 places or more.

A great deal of the engineer's computation is done by means of tables and handbooks. Students should be able to (1) read directions and follow them, (2) interpolate accurately. Hence mathematicians should teach the use of a great variety of tables. Students should not be afraid to use tables. One way to overcome fear is through use.

Students should be taught to use a table for all that it will give. Cutting a 5 place table to 4 to avoid interpolation may be all right for graduates and possible for upper classmen, but it tends to make freshmen and sophomores careless calculators.

Since continued practice in these three kinds of computation is essential for their complete mastery, all computations as far as the mathematics department is concerned should be done by means of arithmetic, logarithms and tables. No slide rules should be permitted.

Engineers and physicists should teach the use of a slide rule. Furthermore engineers themselves should know the theory of the slide rule and how to use it. How many engineers can divide each of a group of numbers by a common divisor using one or at most two settings of the slide rule for the entire group? The answer is, fewer than one would expect.

Nomograms and charts should be taught by mathematicians and engineers but used with judgment by engineers. Our engineering schools are ten years behind industry in the use of nomograms.

Calculations with computing machines can be taught both by mathematicians and by engineers. We should take away from upper classmen some of the drudgery of computation, and release more time to spend on theory.

2. *Each group should point out how various physical concepts are used by other groups.* Much of the confusion of students in such topics as centroids, moments of inertia, and radius of gyration is due to the opposing points of view which these constants receive in different courses. First of all, the student should receive in his courses a sane rational scientific definition of the terms which are used. Such a definition as the one that the centroid of a mass

is the point about which it can be balanced, is absurd. Next, the mathematician, physicist and engineer should point out not only how the idea of mass is used in his subject, but also how it is used in other subjects. Each should show that under proper restrictions one can speak of the centroid and radius of gyration of a line, or an area just as well as he can of a solid. The ideas of centroid and radius of gyration should be freed from the configuration with which they are studied. In computing these constants, mathematicians should develop them from the standpoint of integration, leaving their computation by rule to be done by the engineer.

3. *Show mutual respect.* A united front on the part of the faculty is essential to command respect from the student body and to encourage their loyalty to the school. If mathematicians point out some outstanding achievement of their engineering colleagues, and if engineers adopt the attitude that the department of mathematics knows its business, who is the poor student who would dare to criticize the faculty? The best advertisement an institution can have is an alumnus who is enthusiastic about his college, and that means about its faculty.

(*B*) How Mathematicians Can Help Engineers

1. *Teach mathematics.* This is what good engineers say when mathematicians ask them what they should teach. They also say, teach those things not in practical use so that they can be put into practical use. If the young men know mathematics we can teach them engineering. If they do not know mathematics, we cannot.

Occasionally an engineer, and strange to say, a mathematician will say that only those parts of mathematics should be taught which the engineer uses. There are two fallacies to this statement.

The first fallacy is that no one can say what mathematics an engineer does not need. No one is capable of making such a decision except a great engineer who is exceedingly broadminded, and it is a question if a great engineer would make such a decision. Anyone else who pretends to, is only saying how little he knows about engineering. Any mathematician who has contact with alumni in the field is constantly astonished at the vast amount of mathematics which these alumni seem to need. To make them independent of the faculty would require several more years of mathematics. This, of course, is impossible. The best that mathematicians can do, is to give as good and as broad a course of fundamental mathematics as time permits.

The second fallacy is the assumption that students never forget. There is always a borderline or fringe of uncertainty about any

body of knowledge which an individual possesses. Around and beyond this is the region of ignorance. As time goes on, these regions for any subject shrink until everything becomes ignorance. Anyone who has studied a subject at high school such as Latin and has attempted to do the children's home work for them, realizes how true this is.

There are two conclusions to be drawn from this homely illustration. We must expect to teach these young men far more than we ever can hope to have them remember, and we must not forget that certain items of mathematics are not used by students possibly for a year or more. Instructors of upper classmen must not be disappointed if their students have forgotten some mathematical item. They simply must stop and reteach it. Mathematicians continually have to pause and reteach parts of high school mathematics. Why should engineers be exempt?

As for the uses of pure mathematics once considered impractical, mathematicians can cite such classical examples as complex numbers with electrical engineering; hyperbolic functions with long transmission lines; group theory with quantum mechanics; non-Euclidean geometry with the theory of relativity.

2. *Liberalize the student's education.* An engineer should be educated. His education usually is exceedingly narrow, and pathetically so if his high school training was obtained in a technical high school. There are certain questions that every college man who has had contact with the sciences should know. Illustrations are, the trisection of an angle, infinity, infinitesimals and certain aspects of logic.

Some day the man on the street reads in the newspapers that a high school student has confounded the mathematicians again and has trisected an angle! Is this such a wonderful thing? Can an angle be trisected? Of course it can. What then is wrong? So the man on the street says to the engineer: "You went to college. How about it?" He expects the engineer, a college trained man, to know.

Another concept that an engineer should have is a true meaning of the idea of infinity. The symbol for infinity occurs every time that an engineer sets up a definite integral. One idea that some students have is that infinity is a very large number. There once lived a freshman who thought that infinity was around 150,000, but that was long ago. Engineers should not use infinity incorrectly. Only lady poets should be allowed this privilege.

Mathematicians can help engineers by anticipating and clearing up the mess which students will get into when they reach infinitesimals in the older books in engineering courses. Many engineers are living and writing textbooks, who had their mathematics during

the dark ages when infinitesimals and "ghosts of departed quantities" ruled the land. Infinitesimals as ordinarily used in these textbooks belong to the class of objects characterized by "Now you see it, now you don't." A little explanation by mathematics teachers as to what a student may expect later will go a long way towards clearing up future troubles.

Engineers should be logical. Mathematics presents a splendid opportunity to knock out such fallacies as, if a proposition is true its converse is true, or, special cases prove general propositions. People frequently and unconsciously use these false propositions and are unaware that they do so.

3. *Teach fundamentals with flexibility of mind and resourcefulness.* Some great engineer must have made that statement, because a number of engineers who were interviewed made the same remark. The way for mathematicians to handle fundamentals is to put the emphasis on algebra and arithmetic, and if the officers of administration are willing, keep the freshmen who are deficient in algebra in the algebra course until they get it or get out. The same can be said for trigonometry.

Resourcefulness is intimately connected with flexibility of mind. One way to encourage flexibility of mind is continually to cut across courses by making students use information acquired in a previous course. This tends to eliminate the "box" effect which students so frequently exhibit. If this is done the entire body of mathematics becomes a unified whole, and hence becomes of greater usefulness to students.

Another way to encourage flexibility of mind is to solve the same problem in a variety of ways. No one really knows a subject or a problem thoroughly unless he has studied it from many points of view.

4. *Teach students to visualize.* Everyone agrees that an engineer should possess the ability to visualize. If he does not, his chances of becoming a research engineer are exceedingly slim. Mathematicians should insist that students, whenever possible, should visualize a problem before they attempt to solve it. If this is difficult, actually construct models out of wires, string and cardboard in their presence. Then draw the same object on the board and let the students compare the two. After this has been done for a sufficient number of problems, remove the prop of constructing the figure out of wires. Make the students visualize the figure and then draw it.

5. *Teach students to set up problems.* Engineers say that students constantly have trouble in this respect. The question as to how mathematicians can help is intimately associated with the much debated question of transfer of training. However mathematicians

have splendid opportunities to teach the setting up of problems with verbal problems in algebra and with the definite integral in calculus. No calculus textbook should be used where all the problems can be solved merely by substituting in a formula. Students should be encouraged to learn to set up problems by calling their attention to the fact that when they graduate their employer will not ask them how much is 3 and 4, but will make his demands in verbal form.

6. *Motivate work occasionally by citing an application.* It is only natural that the interests of students will be aroused when they are told of applications which they will later encounter.

7. *Teach students to be independent of notation.* It frequently happened with the older texts that students who had finished calculus could not integrate $t\ dt$, although they could with ease integrate $x\ dx$. All formulas should be expressed in at least two different ways with different variables. This forces the student to free his mind from notation and fix his ideas on the underlying processes.

8. *Emphasize the computation of answers to a certain number of significant figures.* Computation is the lifeblood of engineering. Students should learn to compute early and often. Furthermore they should perceive some significance to the size of their answers. The answer to a problem should be meaningful. If you went to a store and ordered sin 17° pounds of sugar, you would probably be removed from society until the authorities could check up to see if was safe to let you at large. Still we allow absurd answers like this to remain in our mathematical textbooks.

Another thing that should be emphasized is accuracy. Occasionally a problem should be given to a student where he must check his result by some other method than consulting the answer book. Students should have some idea of significant figures and how far they can trust their answers. Mathematicians should give some instruction in the limit of error in computation.

Whenever computation permits, algebra should be applied to arithmetic. Surprisingly few students would do in the best way the computation $(4.716)(3.578)-(2.716)(3.578)$. The fault here is that many teachers of mathematics regard arithmetic as something beneath their dignity and refuse to teach it.

9. *Teach students to form the habit of estimating answers and of avoiding unreasonable ones.* This habit is an exceedingly useful one to form. A student should be taught either to estimate what he expects to get before starting a computation, or else to pause when he gets an answer to see if it reasonable. The question is not one of the desirability of teaching this topic, but is a question of teaching it effectively. One method a mid-western teacher

found particularly effective was to award a first prize to the student who had the largest answer, and a second prize to the one who had the smallest.

10. *Pay more attention to functions as they occur in practice.* Mathematicians will be surprised to learn that functions defined by different laws over a range are not playthings after all, but really occur in engineering practice. One such function occurs with a beam with discrete loadings, another is the current from a half wave rectifier.

11. *Teach topics used by engineers in your institution, even if they are not in the textbook which you use.* Very few textbooks on mathematics are written primarily for engineering students. Consequently certain topics which engineers use are frequently omitted. This means that these topics must be taught by engineers. Other things being equal, a mathematician should be able to teach them better than an engineer. Such topics include Newton's method, Simpson's rule, curve fitting, least squares, elliptic functions and the mean value of a function. The absence of a topic from a text is no excuse for not teaching it.

12. *Look for suggestions from engineers and regard them as helps, not as criticisms.* Find out where the engineers think that students need more mathematics, or where they think that students are weak. You may get some suggestions to improve your courses, or some ideas to make them more interesting. You may discover that some students are pretending they do not know, when they really are too lazy to recall. A united front for high standards is a fine thing for any institution. You may find that you have an impossible situation to overcome, or that you are expected to cover too much work with too poor material. Your engineering friends can help the administration to tighten up on admissions, or to increase the number of hours devoted to mathematics, or to decrease the size of classes. No good engineer expects the mathematics department to solve an unsolvable problem.

Never get provoked if your engineering friends give you a suggestion, even if it is intended as a criticism. Just say that you are glad to know that something is wrong. If you take their criticisms in good faith and with kindness, there will not be any sense for the engineers to get you excited.

(*C*) How Engineers Can Help Mathematicians

1. *Use mathematics.* This means know mathematics, and the best way to learn mathematics is to use it. If the author of the text you are using gives the solution of an equation, be sure that you can solve that equation. If he gives the solution of a dif-

ferential equation, be sure that you can obtain that solution. Do not hope and pray that the text does not contain a typographical error. How can you expect your students to know more mathematics than you do? Some of them are just as glad as you are to take the author's word for it.

Learn modern mathematical methods and use them. Do not use obsolete devices like counting squares for estimating areas. Such methods have come down from one generation of engineers to the next, and often are methods which the mathematicians have tossed in the waste basket years ago.

As an illustration of what mathematics can do, take the case of the problem of a falling body. Without the aid of calculus in physics, a student has to learn several laws. With the aid of calculus, all he has to do is to set up one differential equation, and the resulting solution solves a host of problems.

2. *Recall forgotten facts by reteaching.* Every year students are found in mathematics classes who have forgotten some mathematics like square root, that they should remember. Does the mathematics teacher call them ignoramuses and let it go at that? He does not. He sees to it that they learn square root even if it is necessary to stop right then and there to teach it. When engineers find students have forgotten some mathematics, they should do likewise.

Sometimes students seem to have forgotten some item of mathematics because they find it in a new or strange setting. Explain the new situation to them. Maybe after they have encountered familiar mathematics in several new and strange situations, transfer of training may take place, and they will be able to use the old methods in new places.

3. *Show the connection between symbols as used in engineering and as used in mathematics.* The use of a symbol in a new way is another item that may prevent the recall of a familiar idea. When the instructor finds this to be the case, he can help materially by showing the similarity or the difference between symbols the student is expected to use and the old symbols with which he is familiar. If engineers among themselves cannot agree on a uniform set of symbols, there is not much that the mathematician can do, and it is no wonder that students become confused.

4. *Advise students in selecting electives to elect mathematics.* Naturally some engineers are so wrapped up in their subject that all they can see is engineering. Some mathematicians are just as bad. Nevertheless the fact remains that when a student graduates and goes into engineering, he has possibilities of picking up some engineering ideas which he could have learned in college. His

chances of picking up advanced courses in mathematics are practically nil.

5. *Encourage the administration to form Study Habits Classes.* Most of the engineering teachers come in contact with students only after they have survived the freshman and sophomore years. Only the better students survive those years, and naturally among them are those students who know how to study. The crying need for "How to Study" courses then is not so evident to administrative officers who are engineers as it is to instructors in such subjects as mathematics and English who face the raw freshmen, fresh from high schools where many have just finished having a good time for four years. It is hard for engineers to believe that a surprisingly large percentage of students do not know how to study and do not even know how to read properly. Many students who have sufficient mentality to become engineers are lost to the institution and to the profession through inability to make the best use of their talents. The study habits course should be conducted by a trained specialist, not by an engineer with a few spare hours on his hands. Mathematicians can do a great deal to inculcate good study habits in their students, but they cannot do everything. They can teach them the Gospel of Work. They can tell their freshmen to turn off the radio when they study, and to say good bye to their sweethearts for four long years, but there is much that they cannot do. They do not have the time nor the training to teach them to read with comprehension, to speed up their reading rate and to enlarge their vocabulary so that students will understand the big words that engineers use. The English department can do something, but not much. They frequently have all that they can do to teach these young men how to write English that will not be a disgrace to their college and to their ancestors to the fifth generation. Study habits courses should be a vital part of every first year curriculum. As the high schools get worse and worse, so will the study habits of these young men get likewise.

6. *Exert your influence and insist that only trained mathematicians teach mathematics.* Do not expect last year's graduate to accomplish what only a trained specialist can do.

It is a strange thing that no engineer would ever think of asking a mathematician to give a course in machine design, strength of materials, or alternating currents. Perish the thought! However, many of them think that because an engineer once had a course in calculus he knows all that he needs to know about mathematics and can teach the entire curriculum. Nothing can be farther from the truth. They do not realize that the mathematician who is a good teacher, draws on an enormous amount of knowledge in teaching his classes. In the first place the questions that stu-

dents can ask are astonishing. In the second place, no two classes are taught alike. The instructor tries to adjust his teaching to his pupils. He varies the course from year to year trying to patch up those weak spots he hit the preceding year. An engineer in a good school would be horrified if someone should suggest that a student who had just finished a course in machine design should turn around and teach that course. Yet that, and worse in mathematics, is sometimes perpetrated in the name of education. Even a Ph.D. fresh from the university with a doctorate in mathematics unless he has had years of successful teaching experience, should not be allowed to teach in an engineering school. An engineering student must use mathematics whether he likes it or not and the instructor must be one who can sell mathematics to his pupils so that they will like it. The lives of our boys and girls are too precious to allow their education to be ruined by inefficient or untrained teachers even if they are graduate assistants. Whether engineers wish to believe it or not, an engineering school cannot be any better than its department of mathematics.

7. *Do not expect the mathematicians to perform efficient work while teaching classes of 30 to 40 students.* The ideal class size is more nearly 10 or 15. There are some subjects that can be taught to classes numbering several hundreds, but it is not so with mathematics. Individual differences cannot be handled in large classes in a normal amount of time. Classes for juniors and seniors, a doubly selected group, are usually comparatively small.

The utter indifference of some engineering administrators to the fallacy of large classes in basic subjects is most amazing. Possibly if engineers had large classes and were followed by mathematicians to see how well they taught, they might become exceedingly interested.

8. *Do not expect the mathematicians to teach as applications all the engineering in the curriculum.* Leave something for the engineers to do.

9. *Do not tell the upper classmen that they do not need to know mathematics.* If you say that they never will need calculus after they graduate, you are giving yourself away. Freshmen and sophomores are looking for this kind of encouragement.

Fortunately the old handbook engineer is fast disappearing. His species soon will be extinct. But some of them still are alive, and if their brother engineers cannot handle them, certainly the mathematicians cannot.

10. *Do not expect the department of mathematics to teach more and more high school mathematics, while in the same amount of time they are expected to teach as much college mathematics as they ever did.*

11. *Do not be ashamed to take a course in mathematics occasionally.* Sit on the other side of the desk to see how it seems. Try it sometime and see how critical you become of your own teaching. There is nothing like getting down into a course and working real hard as if you meant it. Possibly you may find that some of the stumbling blocks in the mathematics which runs through your courses may be removed. In any event, you will get something out of the course, and believe it or not, that mathematics teacher whose course you choose to grace will be on his toes every minute that you are there. That ought to be some satisfaction.

12. *Do not call mathematics a tool subject.* Give it the dignified title it should bear. Call it one of the basic subjects. The man who first called mathematics a tool subject should be sitting today in sackcloth and ashes. It is one of those phrases which is not true in the first place, and in the second place it raises up a barrier of antagonism between different departments. Such a barrier ought never to exist. While mathematics and engineering may be considered separate bodies of knowledge, one is just as necessary as the other to the engineer. A tool subject is one which only assists another subject. It has no effect on the mind or the consciousness of the individual. Mathematics, on the contrary, does affect every individual who studies it. A young man who has taken the first two years of mathematics in an engineering school is never the same man again. His mind and his thought processes all have been changed. He thinks differently. He approaches a problem from a different angle. He is a changed creature and he is a better one.

TEACHING VERSUS RESEARCH *

By A. J. McGAW

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During the comparatively short time that the writer has been engaged in teaching he has become aware of certain conditions and attitudes in the profession which he must admit are just a bit confusing. He firmly believes that the most important attribute of a teacher is to be able to teach effectively. Ability to conduct research and training along research lines are, to be sure, essential qualities in the effective engineering teacher; in fact, research is a necessary counterpart of teaching. But the writer wonders if the profession has not become lopsided and if a proper balance between research and teaching exists. If the scales are tipped definitely on the side of research, as the writer believes them to be, then not only is teaching being shoved into the background with a resultant penalty on the student, but research itself is jeopardizing its own position, since it can not hope to serve its purpose without the aid of effective teaching to bring about its assimilation.

Now, in view of what has just been said certain questions naturally present themselves. For example, what reason has the writer for believing teaching is not in step with research and is not as effective as it should be.

In this connection, he has consulted many students and graduates of institutions, not confined to any one region, concerning their opinion of the caliber of engineering teaching. He finds the student and graduate opinion that he has been able to contact to be on the whole very critical of the kind of teaching offered in our engineering colleges. It may be interesting to know, however, that the students and graduates have generally little fault to find from the standpoint of the teacher's knowledge of subject matter. In other words, they are almost unanimous in believing the average instructor is well versed in his own particular subject or subjects. Their major criticisms are that many teachers do not get the subject matter across to the students; that many teachers fail to make their courses interesting, and that many teachers kill all interest the student may have had in the subject before he entered the course. In other words, too many teachers can not teach!

* Presented at meeting of Colorado-Wyoming Section, S. P. E. E., December 4, 1937.

There will be a feeling on the part of some teachers that the student and graduate are not qualified critics of good teaching. Personally I would disagree with this contention and rather would insist one could hardly find a better critic. The student may not be qualified to say whether or not the instructor knows his subject matter. But who knows better than the student whether or not a course is interesting and whether or not he is learning as much as he thinks he should? Also, the student and graduate are too sincere in their belief that too many of their teachers can not teach to lightly waive their criticisms aside.

In view of what has just been said, let us consider briefly what constitutes an effective teacher. Knowledge of subject matter, to be sure, is important. But knowledge of subject matter, regardless of how extensive this knowledge may be, without the ability to impart it to the student is bound to result in ineffective teaching. Administrators and members of the engineering teaching profession have been very adept at enumerating and defining the various abilities the teacher must strive for and attain to become effective as a teacher. For example, he must be able to create and stimulate student interest for the subject and maintain that interest at a reasonably high pitch. He must have enthusiasm for his subject if he would have the student become enthusiastic. He must have a faculty of thinking at the student's level. He must have a full realization of the limitations of the student's capacity for learning. He must have an ability to present material in a simple and clear fashion and, thereby, encourage the student to think clearly. He must have confidence in himself, so that his students may develop confidence in themselves. He must have keen powers of perception so that he may be aware at all times of the degree with which his students are assimilating the material at hand. He must be resourceful in his teaching methods so that he can adapt his presentation to the variable student minds he encounters. He must be conscious of the tremendous responsibility of the teacher to the student and be willing to accept that responsibility fully and completely. He must be willing to assume the responsibility for the student's attitude and interest. He must be quicker to blame himself than the student for poor work in his classes. *He must realize that it is easier to fail a student than to pass him!* In addition to the items enumerated above, which should make for effectiveness in the teacher, the profession demands certain traits such as good character, good moral habits, honesty, broadmindedness, tolerance, etc., as well as superior education and practical experience. One could hardly find fault with this set of specifications.

The student and graduate, however, do not quarrel with the

specifications, but they definitely feel there are too many teachers who fall far short of meeting these requirements. They are crying out against uninteresting and unenthusiastic teaching. They are rebelling against the instructor who conducts his class in a listless, half-hearted fashion. They are denouncing the instructor who painfully derives formulas with constant reference to his notes and text. They are censuring those teachers who are possessed with the unhappy faculty of giving a complexity and obtuseness to those things which are intrinsically simple and who, thereby, confound the student in his attempt to climb out of the confusion. They are condemning the attitude prevalent in some teachers that the student is an intellectual sponge capable of absorbing information just as rapidly as the instructor sees fit to pass it out. They are repudiating the teacher who gets poor student response and interest in his classes and to whom it has never occurred that there might be a high correlation between student response and interest and teacher effectiveness. They are objecting to the teacher who glibly talks out of range and over their heads. They are resentful of the attitude of some faculty members who take a gleeful pride in watching them squirm as they labor over the ponderous and vague questions of an examination. They are scornful of that practice amongst some teachers of measuring their teaching success in terms of the number of students they fail rather than the number they pass. They see the instructor as a demon examiner rather than a sympathetic teacher. Such an attitude between teacher and student is hardly what the profession hoped for when it set up the above specifications for a teacher.

Probably everyone concerned, students, administrators and teachers, agrees that these specifications for an effective teacher are exemplary of all that one could hope for in our engineering college teacher or any teacher. But what steps has the profession taken to assure getting this kind of teacher? True enough, administrators and members of the teaching profession are expounding in S. P. E. E. and other publications the virtues and necessities of effective teaching. True enough, the engineering colleges claim that they have always looked upon teaching as their main function and the quality of instruction as a major responsibility.

But has the profession produced any plan whereby it can determine the effectiveness of individual teachers? Has there been any successful effort to evaluate teaching ability? If teaching is without a measure of its own value, can it hope for any large degree of efficiency? Good teaching like anything else must have proper motivation. It must be provided with a real incentive to improve itself. And there can be no incentive without reward.

It must be demonstrated to the young teacher that his ability as a teacher will be a determining factor of advancement in the profession. Teaching ability must be used more than it is now as a basis for advancement in rank and salary. The rapidity of advancement must not depend entirely on research successes.

But until teaching is properly rewarded it will be left to its own devices in the pious hope it will solve its own problems. For teaching does not have the same opportunity as research to make itself known. Research successes, by their very nature, are self-advertising. They find prominence through publication in the current scientific periodicals and in papers read before learned societies. Good teaching on the other hand seems to have no way of making itself known except through the happenstance gossip of students.

As long as the profession continues to select its young men and advance them entirely on the basis of the advanced degrees they have accumulated and the scientific articles they have published, what is there for the young teacher to do but play the game according to the existing rules? His ears are dinned with a constant clamor for advanced degrees and additional research. If he would move ahead in his profession, he had better collect his medals in the form of advanced degrees awarded for his curiosity concerning the indeterminacy of the arch or the complexities of the Reynold's number. For he sees, in considerable number, men at the top of the profession and younger men moving with certainty toward the top, who are admittedly poor teachers but have done successful research. It has been said in defense of the current practice of using research successes as the determining criteria for advancement that a teacher trying to improve his teaching automatically produces research, books, etc. This has some truth, but does it assure that good teaching in itself will be rewarded? Isn't it rather an admission that the emphasis is being placed on research? The conscientious teacher with a full teaching load may not find it possible to do proper justice to his teaching and at the same time conduct research. The only way that teaching can be assured of its reward and thereby progress is to measure teaching ability in terms of teaching and not in terms of research.

How can the young teacher help but realize his teaching efforts are safe from detection? Will he not be inclined to place emphasis on his research where he knows a reward is awaiting him instead of striking a happy balance between his teaching and his research? No institution would deny that its first duty was to its students and that the student's interests are best served through effective teaching. Yet effective teaching lies figuratively on the ropes waiting

for the profession to determine a method for evaluating and rewarding it and thereby give it a much needed stimulant.

Here, then, is a problem which the profession can not well afford to dodge much longer. It is admitted that the solution will not be an easy one. It will require the concerted effort of the best minds in the profession. But it would be better that the teachers themselves produce that solution. A solution coming from without the profession might be dangerous.

AN ANALYSIS OF FRESHMAN ENGINEERS IN THE UNIVERSITY OF TEXAS DURING THE SESSION OF 1935–1936 *

By MAX FICHTENBAUM

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These are primarily factual data obtained in making various analyses of our freshmen engineering class of 1935–36. Obviously the sample is too small statistically to warrant any definite conclusions or recommendations. At most we can say: here is what we found in analyzing one class; if the information ties in with other data which you have, it may be that you can draw certain conclusions. Furthermore, this discussion may stimulate other investigation along related lines.

A large part of the data given herein involves comparisons of groups of the class according to their rank in the high school graduating class and according to the distribution of the various high school subjects presented for admission to the University.

During the session of 1935–36 we admitted 1042 freshman men, of which number 275 were admitted to our Engineering College.

The distribution by high school rank of these men and those in engineering was as follows:

	All men	Engineer men
Ranked in 1st qr. (highest)	30.6%	26.2%
2nd qr.	29.4%	34.2%
3rd qr.	26.5%	29.5%
4th qr.	11.0%	7.3%

It will be noted that the distribution within the total group and within the engineering group is about the same. Sixty per cent of the total group came from the upper half of their high school graduating classes, and 60.4 per cent of the engineering group came from the same half. This seems to indicate that our engineers had the same proportion of theoretically good students as the freshman class as a whole, consideration being given to the men students only.

When the performance records of the freshmen are checked it appears that this is about correct. An analysis of grade distribution

* Presented at a meeting of the Texas Section, S. P. E. E., Dallas, April 30, 1937.

of the freshmen shows that the freshman engineers earned approximately their share of A and B grades, as is shown in the following:

Freshman engineers constituted 26.4 per cent of all freshman men and earned 25.7 per cent of all A's earned by the group, and 22.6 per cent of all B's.

First quarter freshman engineers constituted 22.5 per cent of all first quarter men, and earned 20.9 per cent of all A's earned by first quarter men, and 19.3 per cent of all B's.

Second quarter freshman engineers constituted 30.7 per cent of all second quarter men, and earned 37.2 per cent of all A's earned by second quarter men, and 27.6 per cent of all B's.

Third quarter engineers constituted 29.3 per cent of all third quarter men, and earned 32.1 per cent of all A's earned by third quarter men, and 24.2 per cent of all B's.

Fourth quarter engineers constituted 17.5 per cent of all fourth quarter men, and earned 50.0 per cent of all A's earned by fourth quarter men, and 17.2 per cent of all B's.

I suspect that your Society is interested in the problem of what subjects a prospective engineer should study in high school, and whether or not certain subjects afford better preparation for engineering work in college than certain other subjects. This is a problem that college faculties have been working on for a considerable length of time, and I doubt that a final answer will be available any time soon. The individual student is such an important factor at this point that I question if we shall ever be able to say that if a student takes certain subjects in high school he will succeed in engineering (or any other profession) whereas if he takes certain other subjects he is quite likely to fail. My observation is, generally speaking, that the strong high school student is likely to do well in college without much reference to the specific subjects he took in high school, whereas the weak high school student will probably have a less satisfactory college record, again regardless of what he had in high school.

We have made various analyses along these general lines, and I shall indicate in a limited way some of our findings.

We found, again generally speaking, that the higher the student ranked in his high school class, the more likely he was to take more than minimums in high school. For instance, it is generally thought desirable for a prospective engineer to take mathematics and science in high school. We found that 22 per cent of the first quarter engineers presented, among other subjects, algebra, plane and solid geometry, trigonometry, chemistry, and physics, whereas only 18 per cent of the second quarter, and 10 per cent of the third and fourth quarter engineers presented entrance credit in these

subjects. If the chemistry and physics are omitted, we find that the four mathematics subjects were presented by 42 per cent of the first quarter engineers, 40 per cent of the second quarter, and 26 per cent of the third and fourth quarters. About one-third of the students in the first and second quarters presented both chemistry and physics, but only about one-fourth of those in the third and fourth quarters presented these subjects. If these two sciences are considered separately, we find that between 50 per cent and 60 per cent of the group presented at least one of them.

It may be of interest to give information concerning the proportion of the class which presented certain entrance subjects:

The combination of algebra, plane and solid geometry, trigonometry, chemistry, and physics was presented by 16.2 per cent of the freshman engineers.
The combination of algebra, plane and solid geometry, and trigonometry was presented by 34.6 per cent of the group.
Algebra, plane geometry, chemistry and physics by 29.4 per cent.
Chemistry and physics by 30.9 per cent.
Chemistry by 57.4 per cent.
Physics by 55.1 per cent.
At least 2 units in foreign language by 81.3 per cent.
At least 2 units in social science by 97.8 per cent.

We have made various investigations of the performance of freshman students, and we have found over a period of years that the average scholastic performance of a freshman has a very definite relation to his performance in high school, as indicated by his rank in high school graduating class. This is, of course, about what you would normally expect. It is of interest to note how close the relationship is, as is shown by the following:

Rank in high school class	Passed minimum requirements		Failed minimum requirements	
	All men	Engineers	All men	Engineers
1st qr.	91.9%	87.5%	4.7%	11.1%
2nd qr.	67.3%	57.4%	26.8%	36.2%
3rd qr.	55.1%	46.9%	35.9%	42.0%
4th qr.	44.7%	35.0%	39.5%	55.0%
Total of all	68.6%	60.0%	23.9%	32.4%

It will be seen from this tabulation that the performance of these students decreases markedly with each lower rank in high school group; that about 9 out of 10 who rank in the highest quarter

will pass, but that only about 4 out of 10 of those in the lowest quarter will pass.

The average performance of engineers in this tabulation is not quite so good as that of all freshman men. This may be accounted for in part by the fact that nearly all of the engineers have mathematics, drawing, and either or both of chemistry and physics in their schedules. These subjects have a higher failing ratio than the general average of freshman subjects, and this is probably reflected in the figures given above.

We have made a special investigation of the performance of our freshmen in chemistry and physics according to whether or not these students presented entrance credit in these subjects. The investigation covered the work of three sessions: 1932–33, 1933–34, and 1934–35.

We found in the case of chemistry that the students who had chemistry in high school had a passing ratio in freshman chemistry about 15 per cent higher than those students who had not had chemistry in high school.

In the case of physics, the percentage variation in favor of the students who had studied physics in high school was even greater —the average variation for the three years was about 21 per cent.

The figures for the three-year period are:

	Percentage of work passed		Percentage of work passed	
	By students who had Chem. in high school	By students who did not have Chem. in high school	By students who had Physics in high school	By students who did not have Physics in high school
1932–33	66.6%	47.4%	72.1%	52.2%
1933–34	73.7%	63.7%	81.8%	58.7%
1934–35	72.6%	56.6%	79.5%	57.4%

The information relating to the proportion of work failed for the same groups is equally significant. In the case of chemistry, the average percentage of failure for the period was 20.6 per cent for those who had chemistry in high school, and 29 per cent for those who did not. In physics the corresponding figures were 13.7 per cent and 30.2 per cent.

The preceding statements about chemistry and physics confirm, in a general way, a similar investigation we made about twenty years ago. From these data we might say, that on the whole, a student who has had chemistry or physics in high school has a considerably better chance of passing college work in the same subject than the student who has not had a preparatory course in the subject.

Furthermore, we found that in general the proportion of A and B grades earned in these subjects was definitely in favor of the students who had the preparatory subject in high school.

Next we wanted to determine if having had the preparatory course in these sciences had a similar effect on good high school students as well as on weak students. We therefore checked the performance of students both according to whether or not they had the same subject in high school and according to the student's rank in his high school class.

We found that a noticeable difference continued, and it was always in favor of the student who had the high school preparation, regardless of the student's rank in high school class. That is to say, first quarter students who had chemistry or physics in high school and who continued the same subject in the University did better in it, on the whole, than those first quarter students who took the course in the University but who had not had a preparatory course in it in high school. The variation was less for the first quarter students than for the second and third.

The average passing ratios for the three-year period are given:

	1st qr.	2nd qr.	3rd qr.	4th qr.
Chemistry:				
Had subject in high school	86.3%	67.4%	53.5%	31.7%
Did not have subject in high school	76.5%	44.1%	31.6%	22.9%
Physics:				
Had subject in high school	88.9%	76.7%	61.8%	35.0%
Did not have subject in high school	76.8%	54.9%	37.0%	33.3%

We were interested in finding out, in a general way, how the student's performance in his freshman work was influenced by whether or not he had studied certain subjects in high school. We have not attempted to make a complete analysis of this problem, since it would require more time than was available. What we actually did was to divide the students into groups according to whether or not they presented, among other subjects, a specific combination of entrance subjects such as those mentioned previously, and then compare the scholastic performance of those who presented this combination with the scholastic performance of those who did not.

In order to make the comparison uniform, in addition to comparing the performance of the groups as a whole, we also compared the work according to the students' high school rank. That is, we compared first quarter students with first quarter; second quarter with second quarter, etc. Furthermore, in order to avoid the

problem that would arise from comparing the work of the first semester with that of the second semester, where a selective factor might arise, we separated the results by semesters.

Three items of comparison were used: (1) the proportion of each group which passed sufficient work to meet minimum scholastic requirements; (2) the proportion of each group which passed at least twelve semester hours per semester; and (3) the proportion of work passed by each group with grades of A or B.

We found that almost invariably the group of students who presented the combination of entrance subjects on which the check was made did better on each of the three criteria than did those students who had not presented these entrance subjects. Furthermore, we found that, in the main, similar results were obtained in the various groups when classified according to high school rank.

We made these comparisons on the basis of ten subjects or combinations of subjects. I shall give a brief summary of our findings for four of these combinations which may be of especial interest to this group.

1. This check involved the groups who did or did not present the combination of algebra, plane and solid geometry, trigonometry, chemistry, and physics. As indicated previously, about one-sixth of the class presented these subjects.

In the first semester, of those who presented the combination, 85 per cent passed minimum requirements; 62 per cent of the other group passed minimum requirements. In the second semester the corresponding figures were 81 per cent for the first group and 70 per cent for the second.

Again, of the group presenting the combination, 77 per cent passed at least 12 semester hours in the first semester, and 76 per cent passed at least 12 semester hours in the second semester. The corresponding figures for the group not presenting this entrance combination were 66 per cent and 55 per cent.

When we checked on the basis of honor grades, that is, A's and B's, we found that the group presenting the entrance credits under discussion earned A and B grades in 47 per cent of their work in the first semester and in 45 per cent in the second semester. The other group earned A's and B's in 24 per cent of their work in the first semester and in 27 per cent in the second.

2. In this check we considered only the combination of the mathematics subjects: algebra, plane and solid geometry, and trigonometry. About one-third of the class presented this combination.

Of those presenting this combination, 88 per cent passed minimum requirements in the first semester and 80 per cent in the

second semester. Corresponding figures for the group not presenting this entrance combination were 54 per cent and 67 per cent.

Of the group presenting these entrance subjects, 73 per cent passed 12 hours in the first semester, and 79 per cent passed this number of hours in the second semester. The figures for the non-presenting group were 65 per cent for the first semester and 47 per cent for the second.

The first group earned honor grades in 42 per cent of their work in the first semester and in 39 per cent in the second. The students who did not present all of this mathematics received A and B grades in 20 per cent of their work in the first semester and in 25 per cent in the second.

3. In this section we used the entrance combination of algebra, plane geometry, chemistry, and physics. These subjects were presented by about 30 per cent of the class.

Of those presenting these subjects, 76 per cent passed minimum requirements in the first semester, and 74 per cent did so in the second. The figures for those not presenting these credits were 62 per cent and 71 per cent respectively.

Of the presenting group, 77 per cent passed at least 12 semester hours in the first semester, and 70 per cent did this in the second. Corresponding figures for the non-presenting group were 54 per cent and 55 per cent.

Those who presented this combination of entrance subjects received honor grades in 40 per cent of their work in the first semester and in 37 per cent in the second. The non-presenting students earned 23 per cent of honor grades in the first semester and 28 per cent in the second.

4. In this check we used the combination of chemistry and physics. Approximately one-third of the class presented both of these subjects.

Of those presenting them, 75 per cent passed minimum requirements in the first semester, and 74 per cent in the second. The figures for those not presenting these two sciences were 62 per cent and 71 per cent.

Of those who presented this combination, 71 per cent passed 12 hours in the first semester, and 77 per cent passed 12 hours in the second semester. The corresponding figures for those not presenting these subjects were 54 per cent and 64 per cent.

Those who presented chemistry and physics earned honor grades in 39 per cent of their work in the first semester and in 37 per cent of their work in the second semester. The other group received A's and B's in 23 per cent of their work in the first semester, and in 27 per cent in the second.

When we compared students of a specific high school rank in the

presenting groups with students of the same rank in the non-presenting groups, we found that practically always the differential was in favor of those who presented the specific entrance subjects under investigation.

Perhaps some data involving those students who ranked in the highest quarter of their high school classes will be of interest.

The following figures are for the first semester:

	Entrance combination 1	Entrance combination 2	Entrance combination 3	Entrance combination 4
Criteria 1—passed minimum requirements:				
Presenting group	100%	100%	95%	95%
Non-presenting group	87%	82%	87%	87%
Criteria 2—passed 12 semester hours:				
Presenting group	100%	93%	100%	100%
Non-presenting group	82%	81%	80%	80%
Criteria 3—proportion of A and B grades:				
Presenting group	66%	58%	47%	58%
Non-presenting group	43%	40%	44%	43%

To summarize briefly: We found—

1. That the distribution of engineering students by high school ranks is about the same as for the total group of freshman men.

2. That freshman engineers do approximately as well in their freshman year as do other freshman men.

3. That generally the stronger the high school student, the more likely he is to take more than minimums in high school.

4. That freshman performance in the University has a definite relationship to the student's performance in high school, and that the good high school student will tend to do well in the University.

5. That students who take chemistry or physics in high school do better in freshman courses in those subjects than do the students who did not have the subjects in high school.

6. That students who take certain related combinations of subjects in high school in general have a better scholastic record in the freshman year in the University than those students who have not had the same combination of high school subjects.

SOME OBSERVATIONS RELATIVE TO THE ENGINEERING CURRICULA ACCREDITING PROGRAM *

By G. M. BUTLER

Member of E. C. P. D. Committee on Engineering Schools and Dean of the College of Mines and Engineering, University of Arizona.

Last year at this time I discussed before this section of S. P. E. E. the engineering curricula accrediting program of the Committee on Engineering Schools of the Engineers' Council for Professional Development. I told you just how we had decided to tackle the problem of preparing a list of accredited curricula and outlined what had already been accomplished.

I now come before you with something more than a progress report since in October of this year a long list of accredited engineering curricula was published as a supplement to the Journal of Engineering Education. You have doubtless all seen that list.

I shall point out later that the publication of this list does not conclude the activities of the Committee as far as the accrediting program is concerned, but it is manifestly true that much has already been accomplished—so much, indeed, that I am in a position to announce some general conclusions that may interest you, without violating any confidences.

The truth of the matter is that the published list tells only part of the story; it does not indicate which curricula were refused accrediting and which were given qualified accrediting, except in the case of agricultural engineering.

By "qualified accrediting," I mean accrediting for one, two, or three years, after which time another inspection must be made. Various situations made such qualified accrediting desirable. Lack of funds or other circumstances may have threatened to impair a curriculum, or there may have been reason to believe that satisfactory plans for improving a curriculum, already initiated and in process of being developed, might not be wholly consummated. It was thought best to give qualified accrediting in border-line cases if it seemed probable that college authorities would thereby be encouraged to make improvements and could later secure unqualified accrediting.

* Address delivered at meeting of Pacific Southwest Section of S. P. E. E. at Los Angeles, Calif., Dec. 29, 1937.

As stated, the published list does not indicate whether the accrediting extended was qualified or unqualified, except as regards agricultural engineering, but the institutions concerned are fully informed about this matter, and know what they must do to secure unqualified accrediting.

It should be mentioned, further, that, because of the terms of the agreement reached with the American Institute of Chemical Engineers, qualified accrediting was not extended to any chemical engineering curriculum.

Not only are the facts about qualified accrediting absent from the published list, but no information is given there about curricula that were denied accrediting.

I am not permitted to tell you what was done about a curriculum or curricula in any specific institution, but I can set forth some figures and percentages that will serve to give you a general idea of the status of engineering education in the United States, and I propose to do so now.

The number of institutions that requested that one or more of their engineering curricula be investigated for accrediting is 134. Five requests were received too late to be considered during the last academic year, so the October report covers 129 institutions, excepting that the decision in one instance was deferred until this year.

It is not known exactly how many institutions there are in this country that grant engineering degrees, but the number probably is about 150, so only about 15 institutions made no effort to secure accrediting, and several doubtless refrained from doing so because they recognized that negative action was certain. One state university that grants engineering degrees is included in the group, however.

All percentages are given in round figures, so they may not add exactly to 100 per cent.

All curricula inspected were unqualifiedly accredited in only 39 institutions, or 30 per cent.

If we consider the institutions in which civil and/or electrical and/or mechanical and/or mining engineering are offered and all such curricula offered were accredited, we find that they number 73, or 57 per cent. This statement means that one (or more) of these curricula was not accredited in 33 institutions, while one (or more) of them was accredited in these same 33 institutions.

Qualified accrediting was extended to one or more curricula offered in 33 institutions, or 26 per cent. No curriculum was accredited in 23 institutions, or 18 per cent.

SUMMARY

Number of curricula considered	626	
Number accredited unqualifiedly	374	(60%)
Number accredited for three years	10	
Number accredited for two years	50	
Number accredited for one year	11	
Number not accredited	173	(28%)
Number upon which accrediting deferred	8	

It may interest you to know that the average number of curricula inspected in each institution visited was 4.9.

It should be evident that engineering education in this country is not all that it should be with only 60 per cent of the curricula unqualifiedly accredited, especially when it is remembered that minimum requirements are deplorably low. I do not know what proportion of the medical and legal curricula were accredited when the doctors and the lawyers instituted their accrediting program, but it is doubtful whether that proportion was as small as is the proportion of engineering curricula that have been unqualifiedly accredited. In other words, there probably existed a greater need for critically scrutinizing the engineering curricula offered in this country than there was for evaluating the medical and legal curricula.

Since each of you is naturally most interested in a specific curriculum, I shall give you the figures relative to the seventeen curricula covered by the October report.

Sanitary Engineering.—All (100 per cent) of four curricula inspected were unqualifiedly accredited.

Naval Architecture and Marine Engineering.—All (100 per cent) of three curricula inspected were unqualifiedly accredited.

Electro-chemical Engineering.—All (100 per cent) of two curricula inspected were unqualifiedly accredited.

(These highly specialized curricula were doubtless all accredited because such courses would probably be offered only in large, well-supported institutions in which satisfactory standards prevail.)

Mining Engineering.—26 of 28 curricula inspected (93 per cent) were accredited, 21 (75 per cent) unqualifiedly.

Petroleum Engineering.—10 of 11 curricula inspected (91 per cent) were accredited, all unqualifiedly.

Metallurgical Engineering.—25 of 29 curricula inspected (86 per cent) were accredited, 22 (76 per cent) unqualifiedly.

Electrical Engineering.—97 of 115 curricula inspected (84 per cent) were accredited, 77 (67 per cent) unqualifiedly.

Mechanical Engineering.—92 of 113 curricula inspected (82 per cent) were accredited, 73 (65 per cent) unqualifiedly.

Civil Engineering.—99 of 121 curricula inspected (82 per cent) were accredited, 75 (62 per cent) unqualifiedly.

Architectural Engineering.—11 of 14 curricula inspected (79 per cent) were accredited, all unqualifiedly.

Aeronautical Engineering.—10 of 13 curricula inspected (77 per cent) were accredited, 7 (54 per cent) unqualifiedly.

Ceramic Engineering.—7 of 11 curricula inspected (64 per cent) were accredited, 6 (55 per cent) unqualifiedly.

Industrial Engineering.—15 of 25 curricula inspected (60 per cent) were accredited, 14 (56 per cent) unqualifiedly.

Chemical Engineering.—28 of 74 curricula inspected (38 per cent) were accredited, all unqualifiedly, but action was deferred in three instances.

(Failure to accredit many chemical engineering curricula was due to low standards, or failure to make the last two years truly engineering in character. Two years of work that is mainly chemistry superimposed upon two years of work basic to all branches of engineering do not make a satisfactory chemical engineering curriculum. Most frequently the work offered in unit processes and industrial chemistry was deficient.)

General Engineering.—5 of 15 curricula inspected (33 per cent) were accredited, 4 (27 per cent) unqualifiedly.

(We found several so-called general engineering curricula that were meritorious. In the last two years of these courses the students were required to do advanced work in at least two different branches of engineering. Some of the strangest courses found were also labelled general engineering. In one of them, for instance, a student was required to lay the usual foundation of engineering in his first two years. In the last two years, however, he largely discontinued the study of engineering and was required to complete 40 semester units of work in any one of the following five fields: Chemistry, geology, physics, economics and business administration, mathematics.)

Agricultural Engineering.—3 of 14 curricula inspected (22 per cent) were accredited, all for two years.

(It was the opinion of the Committee that no course offered in the United States that leads to a degree in agricultural engineering should really be considered an engineering curriculum because the last two years fail to build in an adequate fashion upon the engineering foundation already laid. Most of the courses offered in the last year, for instance, are almost entirely descriptive or vocational in character and students of agriculture who lack training in mathematics and physics can elect these so-called agricultural engineering courses and carry them creditably. Qualified accrediting was granted to the three best curricula inspected in the hope

that they would be further improved within two years. I am convinced that the best training in agricultural engineering is secured by students who elect an agricultural engineering option of a mechanical engineering curriculum.)

Geological Engineering.—2 of 10 curricula submitted (20 per cent) were accredited unqualifiedly.

(Most of the geological engineering curricula were not accredited because too little of the work required in the last two years was really engineering in character. If two years of chemistry superimposed upon two years of the subjects basic to all branches of engineering does not constitute a chemical engineering curriculum, two years of geology plus some descriptive mining subjects superimposed upon two years of these basic subjects should not and does not make a geological engineering curriculum. Physics and mathematics must be used to a considerable extent during the last two years of any satisfactory engineering curriculum.)

The last subject that I shall discuss is the relative quality of the engineering curricula offered in several different types of educational institutions.

It is certain that the state universities and the endowed institutions head the list when averages are considered.

When referring hereafter to "all curricula," I shall mean only curricula in civil, electrical, mechanical, and mining engineering, or as many of these curricula as may be offered, since the action of the committee in regard to more specialized curricula is of much less significance.

Using the term in this sense, in 36 of 37 (97 per cent) state universities inspected, "all curricula" were accredited, in 26 (70 per cent) unqualifiedly.

In 35 of 37 (95 per cent) endowed institutions inspected, "all curricula" were accredited, in 28 (76 per cent) unqualifiedly.

Next come other state institutions, not including agricultural colleges, such as schools of mines, schools of technology, etc. In 13 of 15 (87 per cent) of such institutions inspected, "all curricula" were accredited, but in only 6 (40 per cent) unqualifiedly.

The next group as we go down the list comprises the separate state agricultural and mechanic arts colleges. In 13 of 16 (81 per cent) of such institutions inspected, "all curricula" were accredited, but in only 9 (56 per cent) unqualifiedly.

Below the agricultural colleges come the municipal colleges and universities. In 3 of 5 (60 per cent) of them that were inspected, "all curricula" were accredited, but in only one (20 per cent) unqualifiedly.

Next come the Roman Catholic schools. In 3 of 8 (38 per

cent) of such institutions inspected, "all curricula" were accredited, but in only 2 (25 per cent) unqualifiedly.

The Methodist institutions follow. In one of 5 (20 per cent) of such institutions inspected, "all curricula" were accredited. Since only one institution is involved I cannot reveal whether this accrediting was qualified.

As regards the engineering curricula in one Baptist, one Presbyterian, and one Lutheran institution, it can be said that no curriculum was accredited in one of them, in another, the civil and electrical engineering curricula were unqualifiedly accredited, while the mechanical engineering curriculum was not accredited, and, in the third, "all curricula" were accredited, but only the electrical engineering curriculum was accredited unqualifiedly.

At the bottom of the list are two Y. M. C. A. institutions in which no curricula were accredited.

So, in only 6 of 18 (33 per cent) religious institutions inspected were "all curricula" accredited, and in only 3 (17 per cent) unqualifiedly.

In a class by itself is one Federal university in which all curricula are listed as accredited. Since only one institution is involved, the question as to whether these curricula were accredited unqualifiedly cannot be answered.

The poor showing of the municipal and religious institutions is probably largely due to lack of funds, and indicates that no school should try to teach engineering unless assured of ample financial support. Further, it is probable that the classical tradition may permeate some religious institutions so strongly that instruction in applied science suffers.

What will the Committee do now that the accrediting program is nearly completed? Well, there are several institutions to be visited this winter. In my region, two colleges have recently applied for accrediting. Then there are 78 curricula to be re-inspected in one, two, or three years.

It is certain that a considerable number of the 171 uncredited curricula will be improved in the next year or two to such an extent that a reconsideration of them will be requested.

In addition, it is going to be necessary for the Committee to assure itself that accredited curricula are not allowed to deteriorate to such an extent that they no longer deserve to be accredited. Annual reports of all significant changes will be required of each institution in which there is even one accredited curriculum. If these reports indicate that re-inspections are desirable, they will be made. Possibly it will be deemed wise to send one or two men to every campus at least once in five years.

The program must necessarily be continued indefinitely if it is to possess permanent value.

Other activities will certainly be undertaken by the Committee. Already a sub-committee is considering the problems that have arisen as a result of the increase in junior colleges.

A few persons have inquired as to how the list of accredited curricula will be utilized. If it is used only in advising prospective engineering students where to study, its preparation would certainly be fully justified. It should, however, prove very useful when engineering registration boards are seeking to evaluate the training of applicants for registration, and when college authorities are considering applications for the admission of students by transfer from other institutions.

The Arizona Board of Technical Registration will undoubtedly adopt the E. C. P. D. list as its list of "schools approved by the Board." The graduate from a non-accredited curriculum will doubtless hereafter be allowed only two years of experience instead of four. The boards of other states will presumably follow the same practice.

In the past, the College of Mines and Engineering of the University of Arizona has accepted transfer students from most other colleges, if *the lowest* passing grade had been earned in not more than 20 per cent of the work completed. In the future, the rule will be that *the two lowest* passing grades shall have been earned in not more than 20 per cent of the work completed if the applicant desires to transfer from an un-accredited curriculum and four passing grades are in use. Undoubtedly other institutions that offer accredited curricula will adopt some similar rule.

Regardless of how useful the published list of accredited engineering curricula may be, there is no doubt but that the accrediting program has already done much to raise the standards of engineering education in this country. Some of you who are listening to me know that you completely revised your curricula, enlarged your staff, and secured additional equipment, in order to obtain accrediting. Within the past two weeks, I received from the President of an institution in which no curricula were accredited complete new curricula outlines intended to conform to our suggestions, and a statement of new and materially raised entrance requirements. All over the nation similar efforts to meet the criticisms of regional committees are being seriously made, and many institutions have been provided with powerful arguments for use when they appeal to legislatures or philanthropists for financial support.

The sudden and material improvement of many engineering curricula is the most significant and valuable effect of the accrediting program.

MATHEMATICAL FUNDAMENTALS FOR MODERN ELECTRICAL ENGINEERING*

By H. W. BODE

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The preparation of a mathematics curriculum for electrical engineers is a great deal like trying to pack a very small suitcase for an extensive vacation trip. It is hard to find enough things to leave out. The usual treatment of the problem deals primarily with the relation between the mathematics curriculum and other technical courses. It describes, in other words, some of the definite tools which mathematics must furnish if the student is to master his succeeding training in other scientific and engineering courses.

This list by itself is impressive enough. But there are still other considerations. When we begin a vacation trip we usually know what our destination is to be. It is not so easy to tell where the engineer is going. He may leave school immediately after graduation to work on any one of many specialized jobs in any one of several branches of the electrical industry. He may postpone his departure for a time to take advanced courses requiring substantial mathematical preparation. In either case, we must still reckon with the fact that his professional life will probably last for about forty years. What may seem to be an adequate preparation now may become hopelessly inadequate as a result of developments during that time. We are packing the student's luggage, in other words, without knowing whether we should include a bathing suit or a pair of ear-muffs.

In addition to all of these utilitarian considerations, there is, of course, the final fact that mathematics is part of our general intellectual heritage. The attempt to lay stress on this consideration may seem like a luxury in an engineering course, but I think that it cannot be ignored if engineering is to achieve its full dignity. In other words, the mathematician should attempt to convey to students some conception of the spirit of his subject, rather than treating it as a kit of wrenches and screw drivers for particular purposes.

* Paper presented before the joint meeting of the mathematics and electrical engineering divisions of the S. P. E. E., Cambridge, Mass., June, 1937.

Evidently, we must make some compromise among all these conflicting considerations. We cannot hang over the possibilities endlessly, like a small boy at a cafeteria dessert counter. Speaking very roughly for the sake of simplicity, I think it is fair to say that the usual compromise has been in the direction of providing the student with a limited range of mathematical manipulation within which he acquires great dexterity. The exposition is primarily in geometrical terms. Trigonometry and analytical geometry, of course, are primarily geometrical, and it is usually the geometrical aspects of the calculus which are most emphasized. The treatment is perhaps not very complete or very well integrated from a purely mathematical point of view, since so much attention is paid to gaining proficiency in a rather isolated set of mathematical operations. It does, however, lead to immediate results. It is, for example, of considerable value in preventing the mechanics of mathematical analysis from being a source of difficulty in succeeding technical courses. It is particularly appropriate if the aim of the whole educational process is to turn out an engineer who is in a sense a finished product, with a specialized technical equipment suitable for immediate application in any one of three or four fields.

Electrical engineering is so vast and varied a field that it is rather difficult to make any comprehensive statement either for or against this program. Nevertheless, I believe that on the whole the emphasis in the program should be changed considerably. Even under extreme circumstances, an engineer is seldom called upon to solve so many mathematical problems that the dexterity with which he can manipulate mathematical expressions is a matter of much consequence. Although my own work, for example, is unusually theoretical, I am sure that I solved many more problems in integration while I was studying the calculus than I have done since.

The whole effort to train engineers in the mastery of detailed techniques, while it may be desirable in itself, is, I think, unfortunate if it results in a shortening of the time spent on more fundamental preparation. There are so many specialized fields in any branch of modern electrical engineering that the attempt to turn out a "ready made" engineer who can step directly into the processes of modern industry is a very difficult one. On the other hand, since an engineer is actually at work in only one field at a time, it is a comparatively simple matter to teach him the necessary detailed technique after he is on the job. Major companies sometimes insist on this in any event, if only because their engineers must have a common understanding of technical methods in order to coöperate. Lack of an adequate fundamental training,

however, is not so easily compensated for and may prove to be a permanent handicap.

This point of view is a necessary consequence of the growth in the power and complexity of technical methods. The day is past when an electrical engineer was a man who had some common sense and knew that it took two wires to make a complete circuit. There is now a vast and difficult technique. Moreover, technological development is still proceeding. The television and super-power systems which are in the research laboratories to-day are the staples of tomorrow. Each such development may require a new technical background which must eventually be learned by hundreds or thousands of engineers. In order to see how rapidly such a development may take place, and how sweeping the departures in technical methods may be, we need merely review the history of radio.

With technological progress proceeding at such a rate the case for a specific training for immediate results becomes more and more doubtful. In fact, the victims of such a specific training are liable themselves to become technologically obsolete soon after they graduate. The engineer's salvation must lie primarily in a fundamental scientific training, both because technological advances are increasingly based on pure science and because without such training he cannot keep abreast of technical advances during his working lifetime. As applied to mathematics, this means that the engineer's training should be as rich and diversified as possible. It should offer a ready gateway to any additional preparation which may be needed. In particular, it should emphasize general mathematical principles and methods of analysis rather than dexterity in a few specified fields.

My own recommendation is that the entering freshman should be immediately introduced to a course in the theory of functions of a complex variable substantially similar to that usually taught to seniors or first year graduate students. Naturally, his progress would be slower and it would be necessary to fill out the course with material for practice and with many geometrical and physical illustrations. The broad outlines of the course, however, might well follow that of the usual treatment.

Specificially, the course might begin with a study of the kinds of numbers and with the definition of the complex number. Next should come some problems in computation with complex numbers and a discussion of the ideas associated with the geometrical representation of complex quantities. After this the student might study the behavior of some simple algebraic functions in the complex plan. With this foundation the conception of a limit and the ideas of differentiation, integration, and analyticity can be intro-

duced. They would be followed, of course, by some practice in the use of the differential calculus.

The elementary transcendental functions should be introduced and defined through their series expansions. I would begin with the exponential function and demonstrate its properties by direct manipulation of the series. Trigonometric, hyperbolic, and logarithmic functions would follow as direct modifications of the exponential function. This is in contrast to the usual method in which the trigonometric and exponential functions are introduced separately through reference to the properties of triangles and to compound interest problems, while the mathematical connection between them, which lies at the very heart of theoretical electrical engineering, remains vague in the mind of the student.

Naturally this does not mean that the geometrical and physical significance of the functions should be ignored. On the contrary, this aspect should be introduced and studied in considerable detail immediately after the mathematical foundation has been presented. By introducing the logical mathematical relations initially, however, the student is given a two-sided view of the properties of the functions and at the same time much more powerful tools become available for their analysis.

With this much as a foundation, the rest of the course should follow without difficulties. As time permits, we may include the consideration of other functions, the study of further topics in differentiation and integration, the various ways of representing a given function, the elements of differential equations, and algebra. All of these topics can be treated most satisfactorily with the help of the tools of function theory. The student's mathematical preparation thus becomes a tightly knit whole.

One exception to the function theoretic treatment may be granted. The value to an engineer of a course in probability and statistics is obvious. Present courses, however, are likely to consider only the elementary aspects of probability theory. They deal chiefly with tricks with cards or dice, apparently under the assumption that the engineer will find it necessary to eke out the usual professional income with a little gambling on the side. This treatment may be serviceable in introducing the principles of probability, but to be of real value to the engineer the course should go much farther and be much more realistic. The engineer is seldom much concerned with knowing that the probability of drawing a certain number of red balls out of a box under prescribed conditions is exactly 23 out of 64 rather than 22 or 25 out of 64. He is on the other hand deeply interested in grasping broad statistical situations with sureness and penetration. For example, he may wish to know what conclusions can reasonably be derived

from a set of observational data, and when the data indicate the probable existence of some factor which has not been taken into account. In manufacturing processes particularly, he may want to be able to predict the limits within which, say, 99 out of 100, or 999 out of 1000, of the manufactured product will lie. Although the normal error law will, of course, be his stock in trade, he may also encounter other types of distribution. In other words, the engineer needs a course including a reasonably elementary treatment of a fairly modern brand of statistical theory.

At first glance, the suggestion that function theory be made the basis of engineering mathematics may sound like the story which is sometimes told about the city of Brooklyn. Brooklyn contains a number of old shipping canals, which in the course of the city's growth have been criss-crossed with numerous bridges having only a small clearance above the water. The situation gave the Board of Aldermen much concern. It seemed a pity to use the canals only for small boats, but on the other hand the cost of raising the bridges would have been excessive. Finally one of them had a happy idea which was enthusiastically adopted. They decided to deepen the channel.

Teaching function theory, which is usually thought of in association with questions of rigor, to an elementary engineering class, may seem like the same sort of suggestion. I am recommending function theory, however, for its richness and fertility and appropriateness to electrical engineering rather than for the sake of rigor per se. In fact, I doubt very much whether the function theoretic treatment of elementary mathematics is actually more troubled by questions of rigor than is the ordinary treatment. It is no easy task to teach a course in ordinary calculus which is mathematically respectable and yet distinguish adequately between functions of engineering interest and the less well behaved kinds. The average calculus book takes a paragraph to demonstrate the fundamental rule for finding maxima and minima, and then spends pages showing how unreliable the rule is by reference to functions with discontinuities, nodal points, etc. We have all suffered with the professor who has just triumphantly developed the theory of Taylor's Series and then is pricked by conscience into undoing all his good work by pointing to the existence of functions like e^{-1/x^2} for which the theory doesn't apply. As the presentation is usually made, the student must conclude that the only safe procedure is a direct point by point numerical comparison of the function and the series. Since there isn't much incentive to use the series if one knows the numerical value of the function at every point anyway, this logically relegates the whole subject to the status of an academic curiosity.

All of these troubles are avoided by the function theoretic treatment. The conception of analyticity furnishes a clear and sharp distinction between functions in general and those of interest to the engineer. We can avoid vagueness and half-heartedness in exposition merely by telling the student that singularities are singular.

My intention in suggesting that engineering mathematics should be founded on function theory is not to make it more rigorous, but to make it richer and more diversified and better suited to the students' needs. The essential ideas which the student now receives would still be preserved. The present material of the curriculum is merely reorganized and exhibited with the help of more powerful tools. For example, while I have made no provision for the introduction of analytic geometry as such, the root idea, that of the relation of geometry to algebra, is contained in the geometrical representation of a complex number, and the essential material of analytic geometry can be included while this is discussed. Differentiation and integration and the elementary transcendental functions are of course also included.

It will be noticed that while analytic geometry and trigonometry are introduced into the course, the time spent on them is much less than is customary in a college course. This is done deliberately. I cannot believe that conic sections are as important to an electrical engineer as Fourier Series. While the trigonometric functions are important enough, most of their importance to him is derived from their relation to the exponential, which lies at the basis of a.c. theory, rather than from their geometrical aspects. If an electrical engineer can use trigonometric tables successfully enough to make some sort of solution for the missing parts of any given triangle, it is comparatively unimportant whether or not his processes are somewhat clumsy. For much the same reasons, I would abbreviate, although less drastically, the exposition of the purely geometrical aspects of the calculus.

We must also remember that the greater efficiency of the complex variable analysis makes it possible to cover the same ground in much less time. For example, the equations of straight lines and circles in analytic geometry can be studied through simple linear and bilinear transformations in complex function theory. The army of trigonometric identities, which consume so much time in ordinary courses, can be demonstrated almost with a turn of the hand if we start with the relation between the trigonometric functions and the exponential. The formula for the sine or cosine of the sum of two angles, for example, can be developed in three lines if we begin with Euler's identity, while in ordinary trigonometry it requires a cumbersome geometric argument. Moreover

the process in terms of the complex variable is so much more straightforward that the student can easily reproduce it if he forgets the formulae, something which is rather improbable if the ordinary proof is followed. Much the same remarks may be made about algebra. The function theoretic methods are frequently so much more powerful than those customarily employed in engineering mathematics that considerable economies in time can be made. Since no one, I suppose, would argue that the total time which an electrical engineer spends in mathematical preparation should be reduced, this opens the door to a considerable extension in the amount of analysis which he can learn.

The most direct justification for this proposal is, however, the fact that it corresponds closely to the theoretical foundations of electrical engineering. Ever since the work of Steinmetz and others, a.c. circuit analysis has been tied to the representation of the driving voltage as a complex quantity. This logically demands treatment of the circuit as a whole in terms of complex quantities using algebraic methods throughout. Since the student is ordinarily not very familiar with complex quanties, however, the analysis is usually rendered geometrically. The driving voltage is described as a rotating vector, a vector diagram is constructed, and the student is invited to find the solution graphically from the diagram.

This sounds plausible but the result is very cumbersome. The answer may be implicit in the physical situation, but geometric constructions are notoriously ineffective equation solvers in difficult cases, and the diagrams are consequently often hard to find. Moreover the hybrid analysis which is frequently followed, in which physical variables are used largely in the equations, while the diagram corresponds to the conventions of the complex representation, is very confusing. Taken literally the equations don't make sense, and must constantly be "interpreted."

As electrical engineering advances and our problems become more complicated, these objections must be overwhelming. In communication circuits, at least, the vector method is hopeless. Our circuits are far too complicated for such weak tools, even if we ignore the fact that we must deal with the response over a range of frequencies. A consistent algebraic solution in terms of complex quantities is the only one which is powerful enough for our purposes. This was one of my reasons for suggesting that the entering freshmen should be introduced immediately to the complex number and that his mathematics thereafter should be definitely in terms of the complex variable. I anticipated that he would become so familiar with complex quantities that he would require no graphical aids in the algebra of a.c. circuits. The same reason prompted

the suggestion that Euler's identity should be the point of departure in treating the trigonometric functions. This identity lies logically at the root of a.c. circuit theory and should consequently be second nature to the student.

A second fundamental in a.c. theory is the Fourier Series and Integral representation of an irregular wave. One has only to compare the oscillogram of an actual speech wave, for example, with the idealized sinusoid to realize what a logical gap must be bridged before we can invoke the sinusoidal wave analysis. Again, the simplest path is found by way of function theory.

If for no other reason, I think that the student should be taught something about the logical foundations of such concepts as impedance and harmonics on grounds of professional integrity. At present, an electrical engineer can graduate from many schools without having a really clear understanding of the reasons which make it possible to use an imaginary number to calculate a real physical current, or why it is possible to talk only about sinusoids in spite of the fact that many waves have a very different shape. He may have some vague notions and some rules which usually lead to the right result, but we can say almost that much for popular superstitions about medicine or the weather. If electrical engineering is to call itself a profession rather than a trade I think it is self-evident that its exponents should know something about the principles of their subject.

There are, of course, also incidental advantages to be derived from a function theoretic preparation. As one example, we may take the various circle diagrams which so frequently decorate the textbooks on a.c. machinery. When I first studied this subject I laboriously verified the fact that one diagram after another was actually a circle and I was continually amazed at the thoughtfulness of a beneficent providence in arranging matters so that so very many phenomena could be exhibited in such a relatively simple manner. Some years later I discovered the bilinear transformation and its property of transforming straight lines into circles. If someone had thought to point that out to me as a freshman I might have saved a great deal of labor and amazement.

A second example may be taken from the field of communications. In telephony we frequently have occasion to secure a maximum or minimum of response in a given circuit by the appropriate choice of some disposable impedance. The usual substantial course in the calculus being what it is, it is almost second nature for the engineer to roll up his sleeves and start taking derivatives. Unfortunately, the disposable impedance is usually complex, a contingency which the calculus text overlooked. After some hours of labor, leading to no answer or a false one, the engineer

usually emerges with his confidence in mathematics permanently shaken.

Thus far we have been talking primarily from the point of view of the electrical engineer. The case for adopting function theory as a basis for undergraduate mathematics can, however, be argued more generally. It occupies a central place in mathematical theory and the student who has taken it and desires more specialized training in any given direction is well equipped to go ahead, whether he studies algebra, differential equations, more function theory, or what not. This can scarcely be said for the ordinary curriculum, which offers no ready means of continuing unless one has the time for several advanced courses. Function theory is a particularly appropriate foundation also for courses in the theory of electricity and magnetism since it foreshadows such problems as those of the calculation of a potential field, or of the integration of a magnetic force around loops which may or may not enclose a current.

The ultimate reason for suggesting that function theory should be the basis for undergraduate mathematics is the fact that it should lead to a much richer and broader mathematical foundation. It exhibits more clearly than any other field the wealth of tools which mathematics offers for engineering problems. The methods of approximating a given function furnish a good illustration. At present students are, of course, taught Taylor's Series. This is important enough, but in many engineering problems so much depends upon the way in which the problem is approached that I think the student should be told at least something about the other ways of representing a given function. The proper expansion is frequently half the battle.

It was largely in an attempt to stress the importance of approximation methods to engineers that I suggested that the exponential function should be introduced and defined through its series expansion. This habituates the student immediately to the conception that a function can be represented as the limit of a series of simple numerical operations. Moreover, if we begin with the power series, it is easy to establish the function as a made-to-order result for which the particular form of representation we chose happens to be especially convenient. We have merely to point out to the student how useful a function whose derivative is equal to itself would be in the solution of many physical problems, and then develop the function through term by term differentiation of an arbitrary power series. The remaining properties of the exponential can then be developed as a consequence of this original property.

I would like to suggest in this connection that a mathematics teacher should occasionally step outside the formal limits of the

course to give a brief account of some of the more advanced topics in the field. This is customarily done in other college courses. Undergraduate mathematics, however, is usually presented as a closed subject. The student is drilled on a limited range of topics with no indication of what may be beyond, and absolutely no perspective on the field as a whole. I don't see how mathematicians can expect the engineering profession to make good use of mathematics under these conditions. The engineers have never been shown how rich the field really is. We cannot expect the customers to buy unless we at least take the trouble to put the goods in the showcase.

This general program should be particularly valuable as a means of improving the psychological relation of the engineer to mathematics. Most engineers of my acquaintance show a surprising ingenuity and self-reliance in mechanical affairs, whether they are trying to repair an automobile or invent a new kind of bookcase. They can usually think of half a dozen ways of accomplishing an object. The fact that some of these ways may not be conventional does not disturb them. Within the limits of their knowledge and resources they feel perfectly free to invent and contrive in any way to accomplish a given end.

In the presence of anything which seems to be flavored with mathematics, this attitude changes markedly. The engineer no longer feels confident of his own powers. Unless the situation is perfectly orthodox, with an exact parallel in the textbook, he is lost. And since in engineering the slightly unorthodox situation is very common, and is, moreover the one in which the engineer most needs the power of mathematical analysis to help his thinking, most of the benefits of a mathematical preparation are lost.

I think that this situation is largely a reflection of the way in which the engineer has been taught. He has been drilled in a limited variety of functions, each having its own little set of properties. It is as though each one had been added to the store of knowledge of the human race because a Newton or an Euler made a special trip up the mountain and found it engraved on a tablet of stone. If none of this handful of functions exactly meets a given problem nothing can be done.

This is shown most clearly when a technical advance calls for the introduction of one of the less elementary functions. It is frequently a difficult job to convince the engineer that there is nothing wrong with using such a function if the proper tables are available. The new function didn't come from heaven, and there is something vaguely unethical, if not positively indecent, about trying to use it.

This psychological stymie would be avoided if the engineer were taught mathematics in the spirit of the sentence "Let us de-

fine a function $f(z)$, having the following properties," which appears so frequently in advanced texts. The engineer should be shown that mathematics is a creation, that there are many functions and many ways of representing each function, and that the ones which are chosen for special attention are chosen deliberately for their simplicity or suitability for particular problems. He should be shown in short, that mathematics is primarily a collection of methods and ways of thinking, and as such is capable of infinite extension and flexibility. It is not primarily a memory test in arbitrary, disjointed facts.

The whole question can be epitomized in another way. We are all familiar with the fact that Greek mathematics was primarily concerned with geometry. Such algebra as they studied was elementary and was devoted to the solution of special problems. Even after the Renaissance this tradition persisted. Newton's methods, for example, were highly geometrical. About 1750 or 1800, however, we find that the emphasis in mathematical development changed. Much more attention was paid to analysis and to the development of the concept of function. Prosecution of this new line has led in the present day to much more powerful conceptions than were available in the eighteenth century.

If we review the average mathematical training given engineers, however, we find that it is still eighteenth century mathematics which is being taught. So far as the engineer is concerned, Gauss, Weierstrass, Riemann and Cauchy have never lived. Engineering mathematics still emphasizes the geometrical and mechanical problems which were engrossing to the seventeenth and eighteenth centuries. Such a training might have been suitable for an engineer of that time, when most engineers were concerned with large-scale mechanical problems, but it is scarcely adequate for the subtle and complicated problems of the present day or for those of the near future. We are still furnishing picks when the student will need nitroglycerine.

The mathematics we actually teach our students may possibly be defended on the ground that it is as good as it ever was. But that sounds like the attitude of the man who claimed that if hanging was good enough for his grandfather, it was good enough for him. We could say as much in justification of Egyptian mathematics. If we cannot make a professional mathematician of each engineer, we can at least begin with what appears now to be the best point of view. We did not abandon flint and steel and the Ptolemaic system of cycles and epicycles because they were incapable of starting fires or of accounting for the observed motions of the planets. We rely on matches and the Copernican theory, nowadays, because they are simpler and more powerful. Possibly we need a Copernican revolution in engineering mathematics.

EDUCATIONAL INFLATION *

By HARDY CROSS

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We know pretty well what inflation is. We have heard it promised, threatened or discussed. It tries to make the goods seem more valuable by making plentiful the money used for exchange. Many feel richer; they have more money or can exchange their goods for more money.

I hear the fallacies of inflation vigorously deplored by conservative colleagues; I often find these same men enthusiastic for what seems to me inflation in education. In the educational world the goods is the training of the man, and the thing through which he acquires that training is equipment, faculty personnel and curricula. Some appear to think that if we can increase the number of buildings, the equipment of the laboratories, or the number of courses available, the training will be better and more valuable. A common characteristic of the campus inflationist is that he benefits from the inflation but pays for it not at all; he has a bigger department, more courses, more contacts, without cost to himself: usually he hopes for more money for himself and certainly hopes for more influence. I here indict him as responsible for the penalties that others pay for inflation.

I restrict my remarks to the curriculum because we will all agree—at least some of us will perhaps agree—that students are educated by men and not by buildings or by machines. Was it not the ancient Persians who said that the education of a young man consisted in teaching him to ride a horse, to shoot an arrow straight and to tell the truth? That is all we are trying to do; to teach men to ride a process of reasoning, to shoot home a fact, to be honest in distinguishing what they know from what someone else knows. And I do not like the modification which says that we are trying to teach our men to seem to ride a horse—a hobby horse, perhaps—to produce the illusion of straight shooting—by camouflaging the target—and not to get caught when they talk without knowing what they are talking about.

* Presented before Civil Engineering Division, S. P. E. E. meeting, Cambridge, Mass., 1937.

I am talking here only about the undergraduate course—about the training of you and me when we were twenty or so. I am not talking about training men over forty. Nor am I talking about graduate training; that is another matter, though much of what I have to say applies to it. Nor am I talking about organized research work in the universities.

Many of you know that my remarks are not based alone on observations of any one institution or group of institutions; I have for years had an opportunity to talk with graduate students from many campuses.

Dr. Frederick Keppel of the Carnegie Corporation says: "There is a growing belief that our universities will gain rather than lose by adopting a less costly and pretentious scale of doing things." Growing two blades of grass where one grew before may deserve a medal sometimes, but not if they are made to grow in the wrong place. But he who sets up two courses where one grew before often thinks of himself as thereby a progressive educator and scorns the reactionary who asks whether combining the two courses would not be better.

We have two responsibilities to our boys. We must give them enough vocational education to get and to hold a job till they are rooted in a competitive world. Our other duty—much the more important—is to train them in methods of thinking and investigation so that they can meet the demands of society. None of us can forsee the details of these demands from an ever-changing world, but we can be quite sure that the mental resources needed to meet them will be the same in the future as in the past. Whatever changes take place there will still be an important group of men drawing charts, writing equations, testing materials and hoping that they can interpret the results of the tests; the principles of mechanics and the properties of materials will still be important. There will still be engineers; the more engineers change, the more they will remain the same. It may be desirable that the universities lead the thought of the people: sometimes they do so. But on every campus we hear the puff, puff, puff of professors trying to catch up with the groups they are trying to lead. Often they find out, if they ever catch up, that these groups have got lost from the main procession. As I look back over "new" courses of the past I find that they usually represented detours from the king's highway, not new roads to progress.

We have seen inflation of the curriculum in the past, have watched new animals brought into our educational zoo. Often they were found to be white elephants and later they often turned into dun cows. New stalls had been built for these cows and they had acquired a group of expensive keepers; they were rarely put

back into the barnyard. I have no doubt that in the files of executive offices you would find that some ambitious young man, supported by an aggressive administrator, had clearly proved that these courses were absolutely necessary for progress and had further shown that they would cost nothing—"involve no additional budgetary expense" is, I believe, the proper academic jargon. And yet today many of us wonder why in the world they were ever established at all; "involve no *immediate* addition to the budget and damn the future" would have been more accurate. These new courses are never—"well, hardly ever"—correlated with the regular curriculum, and since the war there has been unusual activity in the development of what purport to be new fields of research. As a result, civil engineering is, in the undergraduate curriculum, becoming pocketed in smaller and smaller pigeon holes with the confusion so often resulting from using a pigeonhole desk.

The most difficult faculty to impart to a student and the most valuable element in his training is the ability to put together his fragments of knowledge in an intelligible picture. Specialization of the undergraduate curriculum goes in exactly the opposite direction. The student is encouraged to synthesize either not at all or ineffectively; he has no guidance and no training in this type of thought.

I am told that multiplication of courses encourages the development of the research attitude among the younger men of the staff and among the undergraduate students. Nearly all engineering is research if by research we mean the solution of a problem not previously encountered in just that form or the development of a new solution of an old problem. But that engineering is chiefly or even largely the method of organized research, as the term is commonly used on the campus, I emphatically deny. I read recently a discussion of teaching in a specialized field of engineering wherein the author emphasized the need of training the students in a half dozen disciplines ranging from thermodynamics to biochemistry. As I read it, like the prophet of old, "I tore out the hairs from off my head and sat down astonished." A well-informed colleague, however, saved such sanity as I have by saying quietly, "That man doesn't know what engineering is." Very, very plausible arguments may be presented for including all sorts of specialized courses in the curriculum. These arguments usually involve the dogma that the universities should solve all the problems of the world in their own walls instead of training men who may help to solve them after graduation. I reject the dogma. Moreover, I doubt whether very narrow specialization ever produces anything of special value.

In discussions of education we often justify conclusions on the logical basis of the traditional reasons for drinking wine—good friends, good wine, or being dry, or fear you may be bye and bye, or any other reason why. I know that each specific digression from the main objective of undergraduate training in engineering can be justified by at least five reasons; occasionally we suspect seven other reasons—five loaves and two fishes. I have watched structural engineering separate into steel engineering, concrete engineering, reinforced concrete engineering, timber engineering, rigid frame engineering, masonry construction—to mention a few. Foundations took its sand hogs to college and came home wearing the insignia of several highhat mystic societies; hydraulics broadened its outlook by taking the grand tour of Europe though it still bores us sometimes by allusions, too forcibly casual, to "when I was at Charlottenburg." Indeterminate structures and elasticity went academic without having to do much travelling at all. Some recent developments in soil mechanics, fluid mechanics or rigid frame mechanics—these examples occur to me as others will occur to you—are valuable. These developments are rarely new in the sense that engineers never thought of any such things before—and if they are new in this sense they are rarely if ever useful. These subjects are not properly independent objectives in an undergraduate curriculum in civil engineering. They belong in the regular established courses not as separate parts of such courses but as perfectly normal developments of the subjects. If they cannot be so integrated they do not belong in the undergraduate curriculum at all.

We want these "new" developments to help do the family work and not shoulder aside the older members of the household. On some campuses there are scholars who are watching the literature and practice in their fields of study, who are estimating the practical importance, the permanence and the training value for undergraduates of any "new" developments and who are year after year modifying their courses accordingly. Other institutions and instructors seem moved to introduce new courses every time a group of papers in some field appears in the technical journals.

Dr. Conant, in a report to the Overseers of Harvard, refers to the "widespread feeling that the separatist spirit of the past quarter of a century has proceeded too far." In the general field of learning this is true; it is becoming unpleasantly true in the field of civil engineering. The standard for training civil engineers cannot be set too high but we must not think to improve this standard by inflation of the curriculum. It is fundamental to distinguish the vulgarity of having too much furniture in the house from the elegance of efficient simplicity.

DEVELOPMENT OF SOME CONCEPTS OF MECHANICS *

By JASPER O. DRAFFIN
University of Illinois

The question may be asked as to why one should read a paper on such an ancient topic when there are many modern, up-to-date themes. My answer is that I selected this topic, when asked to prepare a paper, because I believed in its timeliness. I shall point out how the intellectual atmosphere of a people or a period influences the development of a science and suggest that we need to look into the past as well as the future if our perspective is to be correct. The late President Coolidge, in his inaugural address in 1925, said, "If we wish to erect new structures we must have a definite knowledge of the old foundations." I am convinced that the time has come when our engineering students should have an opportunity to learn more than they have in the past of the steps through which we have come to our present heritage of engineering art and science. Only as they fully realize the social implications in present-day engineering, and how it has grown out of the past, will they be able to do their part in social as well as technical activities. The successful engineer of the future must not only know *how* to do a job but also *why* he does it. The members of the learned professions have enjoyed high esteem in the past partly because they knew the background of their professions. If the engineer is to be most effective he also must know the culture, the background of his profession.

I shall try to present the development of two concepts of mechanics, those of the equilibrium and the motion of bodies. I shall also try to show how the growth of these concepts of mechanics was affected by the thought and spirit of the times. Beginning in a small way about three hundred years before the Christian era, there was complete stagnation of mechanics along with the decline in constructive thought through the Dark Ages. When, after about fifteen hundred years, creative thinking began to reassert itself, mechanics shared in the revival and a little progress was made. Then came the flaming intellectual revival of the sixteenth to the eighteenth centuries and mechanics made its brilliant gains. Finally, a phase which I shall not elaborate, the extension of the

* Presented before Civil Engineering Division, S. P. E. E. meeting, Cambridge, Mass., 1937.

applications of mechanics to engineering, followed the dictum of the power age.

Though equilibrium is sometimes considered as a special case of motion, historically it was developed quite separately. Let us take the idea or concept of equilibrium first, look at the background from which it came and then trace briefly the steps in its growth and development.

A practical knowledge of equilibrium is much older than modern man, for the most primitive man strove to stand without falling down. This practical aspect of equilibrium was later applied to other objects, to his houses or huts, his bridges and his boats. Yet in all this application there was little or no philosophy or speculation as to the relationship between the equilibrium of things and the forces of nature. The builder was a practical fellow and he found, by trial and error, that, if he left out a beam at a certain place, the roof was likely to fall; therefore, he put in a beam at that place. The ancient peoples, the Babylonians and Egyptians, had a practical knowledge of equilibrium, but their mathematical knowledge of it, if they had any, was not transmitted to us.

This brings us to the early Greeks, that remarkable group of people, still regarded by many as having possessed the ultimate in art, culture and philosophy. Why, with all their mathematical and reasoning ability, did they not develop more of the principles of mechanics than they did? To understand this we must remember that the difficulties which the builder and artisan had in making his structures stand were of little or no interest to the Greek philosopher. Work with the hands was considered low and mean and those who did this work belonged to the lower stratum of life. The thinker was concerned with social customs, questions of immortality, justice and truth, elements which entered to some degree into the thought and understanding of all people, rich or poor, educated or unlearned. Logic was the accepted mode of reasoning and experimentation was an unworthy tool for a scholar to use. Consequently the setting, the background, in which any knowledge of mechanics must originate and grow was decidedly unfavorable to it.

The first writings on mechanics of which we have a clear record are attributed to Aristotle (384–322 B.C.), though they were probably not written by him. These writings consist of 35 problems or questions of a mechanical or physical character. One question is "Why do small forces move great weights by means of a lever, when they have thus to move the lever added to the weight?" "Is it," he asks, "because a greater radius moves faster?" Concerning the lever he says in part: "As the weight moved is to the moving weight, so is the length (or distance) to the length inversely. . . . The reason is that . . . the line which is farther from the center

describes the greater circle, . . .'' * Notice that he observed correctly the action of a lever but explained it in terms of circles, which, as we shall see latter, was in accord with the prevailing philosophy. The knowledge of mechanics in Aristotle's time was indeed both meager and sterile.

The real beginnings of a mathematical or reasoning knowledge of equilibrium began with Archimedes (287–212 B.C.). Though he was a Sicilian, this mathematician and mechanical engineer was imbued with the Greek view of scholarship. He meditated on mechanics and discussed principles but disdained to experiment. To learn or to try to acquire knowledge by mechanical means was beneath the dignity of a scholar and an abuse of the powers of the human mind; he would not even publish his engineering writings. This man established the so-called law of the lever on the proposition that a lever with two weights on it will balance when the distances from the fulcrum are inversely proportional to the weights. The method which he used in his proof embodies the principle of the center of gravity which involves moments of forces and thus Archimedes really made use of equality of moments even though he did not perceive the fact. The really important thing to be noted here is that, for the first time, a definite principle or law was set up in which equilibrium was defined in terms of lengths of the lever arms and weights.

The law of the lever represents all of the advance which was made not only during the life of the Roman Empire but for centuries after its fall. We should, however, remember that the barrenness of the Roman period in scientific advance was not due solely to the bondage to Aristotle. The Roman as a people contributed little to scientific advance because they concentrated their efforts on government and war. Someone has aptly remarked that the Roman spirit was well exemplified by the story of the soldier who killed Archimedes while he was solving a problem in geometry. The soldier knew nothing of geometry and cared less.

It is often difficult to say precisely when or by whom a particular idea or method is perfected and so it is with the moment of a force. Not until Europe began to turn and writhe in its mode of thinking, in its desire to question nature at first hand, was there any progress in mechanics beyond the law of the lever. The Italian Renaissance brought Benedetti (1530–1590) who, in a book published in 1585, is said to have defined moment of force in its modern sense, and it also brought da Vinci who used the correct moment arm in his discussion of pulley systems. Nevertheless Professor Crew says, ''it may be fairly doubted whether either of these men ever thought of

* Heath, Sir Thomas, ''A History of Greek Mathematics,'' Oxford, 1921, Vol. I, pp. 344–345.

the product of lever $\times$ force as constituting a single quantity.'' * Varignon, in his book ''Projet d'une Nouvelle Mecanique,'' published in 1687, used the moment of a force in its modern sense and since that time it has been an accepted concept, with a definite meaning, in all writings on mechanics.

The next advance to be chronicled came from Leyden, where the University of Leyden was located, in the sixteenth century. All over Western and Southern Europe there was a fierce struggle and constant warfare as groups strove either for freedom or for advantage. Navigators were scouring the seas to bring lands and plunder to their monarchs and riches and fame to themselves. As a part of this general turmoil a bitter political and religious struggle raged between Spain and Holland and out of it was born, in 1575, the ''Athens of the West.'' A child of the struggle, the University of Leyden stood irrevocably for free thought and learning. Under such influences Simon Stevin (1548–1620), the mathematician, the public accountant, the military engineer, achieved a solution of the inclined plane in 1586. This method dealt with forces instead of moments.

His method of attack was by imagining an endless chain placed over two intersecting planes of a triangular prism. He reasoned that if the chain would not slide either way there must be as much force acting down one plane as down the other. From his study of the inclined plane came the law of the parallelogram of forces. Though Stevin did not specifically state the law, the idea was clearly there. A century passed and then, in 1687, Newton, Varignon and Lami, each independently, brought out the principle in its present form. In spite of the fact that the work of Stevin was remarkably clear for that time, it made but little impression, probably because the political and religious confusion was too great—he was ahead of his time. A hundred years later Varignon (1654–1722), using many of Stevin's ideas, presented the concept of equilibrium by considering a body with a number of pulls acting on it, the pulls representing the forces in magnitude and direction, essentially the method used today.

Summarizing, we may say that for a body to be in equilibrium the moments of the forces must be equal to zero. But rotation is not enough to ensure equilibrium since translation may take place. By the extension of the principle of the parallelogram of forces, by combining and resolving forces, the conclusion is finally reached, that equilibrium exists with respect to translation when the sum of the forces in each of the x, y, z directions is zero. For the first condition we go back to the contributions of the age of

* Crew, Henry, ''The Rise of Modern Physics,'' Williams & Wilkins, Baltimore, 1928, p. 79.

authority, to Archimedes. For the second condition we use the ideas of forces, their summation, composition and resolution, the contributions of Stevin, Newton and Varignon, those intellectual products of the Renaissance. Thus the development of two ideas, separated in their beginning and completion by nearly two thousand years, ideas of moments and of forces, gives us a picture of the growth of our knowledge of the equilibrium of a body.

We come next to the concept of the motion of bodies. If the views of Aristotle were vague on equilibrium they were much more vague on motion. To understand this it is necessary to look for a moment at the conception of nature held by Greek philosophers. The doctrine of opposites was prominent, such, for example, as fire and water; fire was hot and dry, water was cold and wet. They divided motion into two kinds, natural and unnatural; the first was of the common type such as that of a freely falling body; the second kind was that due to some sudden or violent action. To add to the confusion, the terms which they used, such as force and pressure, had no fixed and definite meaning.

Further, they believed that all bodies had a place in the universe and sought that place, that is, light bodies moved upward and heavy bodies moved downward, as for instance, a block of wood and a stone, both immersed in water. They believed that heavier bodies fell faster in air than light ones. Add to these beliefs certain other prevalent ones; namely, that the circle was the most perfect form of figure; the earth was imperfect because the surface was manifestly uneven; the orbits of the stars were apparently circles and were therefore perfect, while above and beyond the stars was God who was absolute perfection. Such were some of the confused ideas held by the Greeks and we must take them into account in order to understand the tremendous changes which had to occur before correct concepts of the motion of bodies could be formulated.

Aristotle and those of his school observed physical facts and asked questions about them. As for instance, "Why can a man throw a stone farther with a sling than with his hand?" Yes, they observed facts and asked questions but they did not search for a common basic principle in the answers, and experiments were out of the question for scholarly philosophers.

The followers of Aristotle, who almost worshipped him but taught his ideas from faulty translations, were more rigid than Aristotle himself. Consequently beliefs did not change much for nearly two thousand years, though there were those who asked inconvenient questions and proposed unorthodox answers, sometimes at considerable risk to themselves. A new day was dawning. Nevertheless, most of the questions of mechanics remained unanswered until Galileo (1564–1642) brought a vigorous imagination,

a daring spirit and an open mind to study them. Whether or not he questioned the accepted belief that heavy bodies fell faster than light ones, he certainly would not accept the proposition without proof. He dropped balls from the leaning tower in Pisa, at least it is so stated, and, with others who scoffed at him, observed that both large and small balls which were dropped at the same time reached the ground together. In his writings Galileo guards himself against a possible disproof of his argument about falling bodies by saying that a slight variation from absolute equality of velocity for light and heavy bodies must not be taken as rendering the law void. In other words, he recognized and pointed out the probability of experimental error. We can hardly appreciate today the remarkable gain which Galileo made for science when he admitted that his results might be only approximate. The prevailing belief of that day was still in authority, in the absolute.

As a student Galileo was a thorn in the flesh of the faculty at Pisa and as a member of the faculty he was even worse. He had a hard time getting his appointment as a professor and his salary was only one-tenth as much as that of the professor who taught civil rights. He was a cantankerous fellow, a young upstart who did not know his place, and his colleagues were not backward about telling him so. Finally he left and went to Padua. Doubtless he was about as agreeable as a burr under a saddle but he did one thing to perfection—as Professor H. F. Moore says, "he made experimental work respectable."

Along with his study of the acceleration of freely falling bodies, Galileo gained a fairly clear conception of the fact of inertia, though he did not express it in a direct manner, and finally, he adopted a definite quantitative measure of motion, namely, momentum. His ideas were not enunciated in the form and terms which we now use but the substance was there. One statement is a restricted case of Newton's first law of motion and implies that the particle has that property which we call inertia.

Galileo began his reasoning on motion by experimenting with methods. He first tried to establish the relationship between velocity and distance but found difficulties. He next tried the relationship between velocity and time and conducted physical experiments with a high degree of success. One experiment consisted in rolling balls down a plane inclined at various angles with the horizontal. The capstone was put on the work of Galileo by Newton, born the year Galileo died, who added the ideas of force and mass and thus completed the force-mass-acceleration concept of bodies in motion.

In spite of the fact that it was fifty years before Galileo's kinematical work received its crown at the hands of Newton, that fifty

years was full of brilliant achievements for mechanics. The period was one of advance in all directions, political, economic and intellectual. Though men were still not allowed to express what they thought in some places, there was immunity in other places. In Leyden, as pointed out while discussing equilibrium, there was freedom of thought. In this city, which had purchased freedom with blood, Huygens (1629–1695) attacked the problem of moving bodies from a point of view different from that of Galileo. Huygens carried out his researches from the view of work and energy, though he did not so label them, and specialized on circular motion and the pendulum. His work on the pendulum was so complete that the basic elements of the pendulum clock are today essentially as he left them. At times he used the force-mass-acceleration (or impulse = change of momentum) ideas, but he used mostly the force-distance (or work = change in kinetic energy) idea. The distinction between weight and mass was not perceived by Galileo but seems to have been pointed out by Huygens when he referred to "solid quantities" of matter and urged the trip of Jean Richer who investigated the seconds pendulum in 1672. The final, formal expression of mass was due to Newton.

The intellectual advance in the seventeenth century was remarkable. In mechanics and related subjects there were many workers with diverse points of view; new terms were introduced, definitions were clarified and the science took on a certain aspect of completeness. Out of the give and take of the different approaches arose one of the most famous disputes in the whole history of mechanics, one which lasted for over fifty years, the Descartes-Leibnitz dispute. The Cartesians followed Galileo who had found that for a given body the quantity of motion varied as the first power of the velocity. The Leibnitzians espoused Huygens who had found that the quantity of motion varied as the square of the velocity. Certainly both could not be correct and so the dispute raged. The kernel of the whole controversy lay in the fact that neither side had completely defined the term "quantity of motion" and each side used a different measure. The matter was not settled until 1743 when D'Alembert pointed out that the quantity of motion used by Descartes referred to impulse while that of Leibnitz referred to work. Both were right, there were two entirely different ideas. D'Alembert's explanation settled the matter except for those who still wanted to argue.

Thus, if we omit Archimedes' work, practically all of the principles of mechanics were elaborated in a period of less than 160 years. This accomplishment took place during the time which compassed that phenomenal intellectual advance in nearly all phases of thought, the Renaissance. We should remember, however, that

only the principles were evolved in the 160 years of progress. The applications of the principles to engineering have been made since then rather steadily. That progress is still under way, not only in mechanics but in all branches of engineering, and I am advocating that this continuing, living, growing, thinking point of view shall be more fully presented to students. Our future engineers need a background as well as a foreground in order to keep advancing.

THE PLACE OF THE TECHNICAL LIBRARY IN ENGINEERING EDUCATION *

By RUTH McG. LANE

Vail Librarian
Massachusetts Institute of Technology

Library usage is a basic function of all education. Every engineering school has a library. Engineering educational methods require comprehensive knowledge of highly specialized technical literature, and expert ability in its use. Library research is therefore an integral part of every engineering education program. Library research technique is comparable to laboratory research technique in educational value. The values of the "library habit" are permanent. The engineering librarian has definite educational responsibilities.

Dynamic intelligence, creative resourcefulness, productive thinking—such attributes are admittedly essential to a successful engineering education, but the value of the engineering library in developing these attributes is not so widely recognized. That familiarity with the literature of his special field is essential for the graduate engineer, is also admitted, but the process by which he, as a student, is to acquire this familiarity is not well defined.

Library Usage

Preparatory

Library usage is an integral function of all education. Elementary school pupils are taught to know their public libraries. The School Library, with training in its use as a regular part of the curriculum of instruction, is an essential feature of every secondary school.

Colleges and universities therefore assume that their entering students have already acquired this knowledge of fundamental library procedures—classification principles of arrangement, card catalog interpretation and manipulation, book borrowing technique, and the use of general reference books—and in the majority of cases limit their bibliographic teaching to the mere continuation of secondary school library instruction on an extended scale as re-

* Presented (in part) before the S. P. E. E. Electrical Engineering Division, M. I. T., Cambridge, Mass., June 29, 1937.

quired by the library facilities of the larger institutions with little change in instructional methods or interpretation, except in the application of the library conditions and rules of the specific institutions. Freshmen are introduced to the Library early in their first semester, or during the orientation week set aside for their special reception before the opening of the academic year. Printed information about the Library is included with their registration material; descriptive details are to be found in the Catalog of courses; and sometimes a Library Handbook, or Manual, is available. Guided tours of the Library are arranged; Library assistants explain the necessary routines of usage, and the location of specific reference books and tools; the Librarian talks to the group as a whole. Certain courses require greater use of the Library than others, and the instructors of such courses either give themselves, or arrange to have members of the Library staff give, more detailed instruction in library technique. But in the majority of cases, after the preliminary general introduction, any follow-up is left to individual student responsibility and only the exceptional student uses his own initiative to carry on further investigation of the library's advantages.

Engineering Schools

In engineering schools many students have gone through the entire four-year course to graduation with negligible knowledge of actual practice in library usage. The record of the student without library knowledge may be as good as that of the student with such knowledge; but the student who goes on into graduate work is handicapped at once, if he does not know the principles of library research. Furthermore, measurements of professional success five years after graduation would undoubtedly give a higher rating to the man who possessed the "library habit," the ability to make adequate use of technical literature, and the background knowledge which is the natural result of such use. The apparently successful completion of undergraduate engineering study with little emphasis on the library as a pedagogical feature of the course has resulted in an underestimation of the educational values of the engineering library. Recent changes in methods of engineering teaching however, particularly in connection with the problems of the increasing number of graduate students who must carry on independent research, indicate a reconsideration of the status of the library in the educational program.

Engineering School Libraries

In all of the degree-granting engineering schools in the United States there are Libraries. These libraries, though similar in gen-

eral literary characteristics, are extremely dissimilar in physical structure, professional administration and use. Ranging, as they do, from the Polytechnic Institute Library of several hundred thousand volumes to the small collection of a few hundred books in the office of a single engineering department in a large university, these variations are inevitable. According to categorical classification, the engineering library is primarily departmental, in that it serves a highly specialized field of study. In physical structure it may be centralized within the larger complete library of the institution, being departmental in service only; it may be a library of considerable size, distinctly decentralized as a separate departmental library in the engineering building; or it may be a small collection of books and serials—the outgrowth of special interests of department faculty members—maintained in the headquarters office of a specific engineering department.

A rough estimate * shows that the libraries of our 19 Polytechnic Institutes alone have nearly 1,000,000 volumes and subscribe to some 5,500 current periodicals and serials. Total library resources of Polytechnic Institutes, Schools of Mines, and Land Grant Engineering Schools approximate 11,125,000 volumes and 70,000 current periodicals and serials. Engineering departmental libraries in universities average 13,600 volumes, the largest having from 20,000 to 35,000 volumes.†

Library as a Function of Engineering Education

The adequate use of such libraries is an integral part of engineering education. The engineering librarian has a basic educational responsibility. The engineering library, administered by a librarian familiar with the special field of literature and with educatonal aims and methods, has a functional value equal to that of the laboratory and classroom.

Educational Objectives

What are the fundamental objectives and methods of engineering education which require comprehensive knowledge of highly specialized technical literature and expert ability in its use? For these are the educational methods and objectives with which the engineering library is concerned.

Professor Dugald C. Jackson, Head of the Department of Elec-

* Figures estimated from American universities and colleges. Edited by C. S. Marsh, for the American Council on Education, Ed. 3, 1936, and from various Engineering School Catalogs.

† Wightman, Clifford B. Survey of engineering and technical departmental libraries in U. S. and Canada. Unpublished Mss. University of Michigan Dpt. of Library Science. 1933.

trical Engineering at M. I. T. for nearly thirty years and now Professor Emeritus, has always urged upon his students the prime importance of the investigatory spirit, the resourceful mind, and the value of independent achievement. In expression of his educational philosophy he has repeatedly emphasized the need for comprehensive libraries, comprehensive reading. Other objectives of engineering education as stated by many educators are definitive knowledge, vicarious reasoning, scientific habits of though, creative intelligence. All these are elements of high mental ability and assume, as a natural corollary, a thorough understanding of technical literature and its use.

To attain these objectives the engineering student must acquire keen appreciation of the values of reading technical literature; thorough comprehension of the scope of the literature of his special field; exact knowledge of the technique of finding required information in this literature; and an instinctive desire to construct for himself as wide a background of technical intelligence as possible. He must develop the power of using the vicarious experience which he gains from the printed page. The engineering library is the laboratory for this part of his education, but, in order that his accomplishment may be adequate, there must be expert guidance and instruction in library usage, supplementary to the general Library orientation of Freshmen and given by departmental reference librarians who are specialists in the literature of the various engineering fields. Certain supporting conditions are presupposed: sound professional training and knowledge of educational methods on the part of the librarian; adequate financial support to permit the continuing growth of library facilities; sympathetic cooperation between instructing staff and librarians.

Educational Methods

Certain engineering educational methods require this collateral instruction in library research techniques—the project method of instruction, the seminar, the comprehensive examination, the thesis, graduate research. With more and more emphasis on individual thinking and less required study of specific textbooks, the engineering student does a correspondingly greater amount of his work in the library. His instructors and librarians must therefore work in close coöperation as directors of his research there. Library problems have acquired very definite educational implications.

Library Instruction

Library instruction in higher education is not new. Lectures, with or without problems or exercises; instruction through individ-

ual consultation; manuals on the use of books and libraries—have been available to students in colleges and universities for a considerable period of time, but specific applications to engineering curricula are few. The development of such instruction as a definite feature of engineering education seems to be still in the experimental stage, or perhaps in that halfway stage, apparently adequate for past needs, hopefully meeting present problems, and hesitant to begin the attack on inevitable demands of the future.

Vail Library of Electrical Engineering

When the first electrical engineering students at M. I. T. graduated in 1885, very few books were available for their study. The Vail Library of Electrical Engineering now comprises over 40,000 volumes; the Institute Library as a whole contains over 300,000 volumes. The educational philosophy underlying the administration of the Vail Library has always been that library usage is an integral part of electrical engineering education; that the scientific technique of library research is comparable to that of laboratory research; and that the classroom, the laboratory, and the library are interdependent functional units in the educational process.

Vail Library Educational Procedure

I propose now to detail briefly the educational aims and activities of the Vail Library and hope to prove by implication that similar procedures could, and should, be adopted as an integral part of the educational program of every engineering school.

At the beginning of their professional course in the second term of the Sophomore year students in Electrical Engineering attend a series of weekly orientation lectures. One of the first of these lectures is given by the Vail Librarian and includes the history and scope of the Vail Library; its status as a technical library and as an integral part of electrical engineering education; techniques of its use; methods of bibliographic searching by means of source materials and essential tools; and the intrinsic values to be gained from a wise comprehension and use of the literature of electrical engineering.

Immediate contact with library practice is made in the required work of the course in electrical measurements which is taught by the project method. No single textbook is used. A syllabus briefly explains problems suggested for experimental demonstration and cites in the case of each problem references to technical literature for reading preliminary to consultation with the instructors and subsequent laboratory work. All of the reading matter—problem

notes, as well as books, periodical references, reprints, bulletins, etc.—is kept at the Vail Librarian's desk. The librarian accordingly has the immediate opportunity for consultation and informal discussion of library values with the individual students.

A brief description of the administrative set-up of the Vail Library may be appropriate at this point. The Vail Library, which has grown out of the original Vail Collection of electrical engineering amassed during the last half of the nineteenth century by George Edward Dering of Herts, England, and purchased in 1912 by Theodore N. Vail, President of the American Telephone & Telegraph Company, for presentation to the Department of Electrical Engineering, M. I. T., is a centralized departmental library. Although primarily serving one department, its books are shelved in the stacks of the central Institute Library and the Vail Librarian's desk is located in the main reading room. The section adjacent to the Vail desk is known as "E. E. Ref."—Electrical Engineering Reference—and here is concentrated a collection of electrical reference material—several hundred books used as course references; handbooks; duplicate copies of bound periodicals for the last five years; special notes, reprints, bulletins, etc. Just beyond are the current issues of over a hundred electrical engineering periodicals, and the adjacent reading tables are reserved for electrical engineering students.

Through almost daily use of this "library within a library," electrical engineering sophomores become well acquainted with the basic literature of their profession. During this first term of their professional study the Vail Librarian works with two very definite aims: 1, the guiding to an appreciation of the literature of electrical engineering, its tremendous scope, its professional and inspirational values; and 2, the interpretation of this literature through knowledge of source materials, types of publications, and authorities. Certain skills necessary for library research—alphabetic and numerical sequence skill, classification sense, and correlation ability—can be developed more readily in the use of this limited reference collection of specialized technical literature. The "E. E. Ref." book section is an epitome of the complete collection in the closed stacks of the Institute Library, and the student who acquires familiarity with its arrangement and classified subdivisions quickly develops adaptability to the use of the entire library when, as upperclassman, he has stack privileges. The privilege of entering the main book stacks is granted to Honors Group Juniors, all Seniors, and Graduate students.

In this first library reference work, carried on by voluntary conference method, there are countless opportunities for noting special interests, special needs. The personal equation is very im-

portant at this crucial period in the student's educational career; coöperation between departmental librarian and instructing staff may help to solve difficult individual problems. Many cases for future "follow-up" in library contacts are noted.

In the Junior and Senior years, at the present time, library lectures are scheduled for Honors Group students only. These small selected groups study under counsellors, following a flexible curriculum, with the seminar type of group discussion supplementing class recitation. Emphasis is placed on individual investigation, discussion contribution, and comprehensive reading. Consequently, the library holds an important place in Honors Group work.

The Library lectures are expanded to include techniques of research in technical literature. To the basic principles of the library catalog—classification, alphabetization, bibliographic terminology—are now added the details of periodical indexes, technical abstracts, and comprehensive bibliographies. Such skills as reading ability, thinking power, particularly the power of critical evaluation and condensation, and language facility, both English and foreign, are emphasized. The library is interpreted as a working laboratory in technical literature, and bibliographic records, comparable to experimental laboratory notebooks and reports, are recommended.

Honors Group students respond one hundred per cent to library opportunities. Junior and Senior library lectures are given in the seminar manner with questions and discussion. The Senior lecture supplements that of the Junior year with more detailed discussion of the library values which look toward the future engineer's professional development after graduation.

The three lectures just described offer therefore a brief progressive course in engineering library practice. The Vail Library lecture to graduate students falls in a slightly different category. Part of the requirement for the Master's degree is the preparation of a dissertation upon the historical development of some phase of electrical engineering. Correlation between seminar dissertation and thesis is advocated, so that each student spends considerable study time in a chosen field, and a definite period of library research is specified. Particularly for the benefit of those graduate students who come to the Institute from other colleges and universities for that one year only, the library lecture given as part of the general introduction to the Seminar work summarizes the important details of the previous lectures and emphasizes the library techniques and values essential to any comprehensive bibliographic research in the field of electrical engineering. This group lecture is then followed by individual consultation with each student and guidance in the beginning of the necessary bibliographic research.

Educational Philosophy

Underlying these Vail Library activities, both group and individual, is a definite educational philosophy which has a twofold purpose: 1, the supplementing of departmental instruction in the solution of those academic problems which only library practice can solve; and 2, the encouragement of that spirit of interested investigation and intellectual alertness which develops mental facility in reading and writing, and will lead to the broader comprehension of engineering which new aspects of the profession are demanding.

Library Usage from the Student Viewpoint

The student viewpoint of library usage gives support to our theory and practice. As he proceeds with his professional study, he is faced with at least three problems which lead to the library for solution. He needs to acquire, 1, comprehensive knowledge of the technical literature of his special field, in order that he may follow and understand future developments; 2, appreciative understanding of his chosen profession, its aims, methods, and accomplishments; and 3, vocational information concerning the actual work available to him in that profession. Classroom lectures, seminars, colloquia, all introduce him to these phases of his education, but the details he must search out for himself.

In this search he may at first be appalled by the extent of engineering literature, but a few hours of guided library exploration plus a few hours of independent investigation will give him a fundamental understanding of its intricacies. Mastery of bibliographic terminology and symbols will soon follow, and the adaptation of such technique to his own note-taking and data-recording will lead him to the desired comprehensive knowledge of technical literature and will enable him to contribute to the literature of his special field. The words, comprehensive knowledge, are not meant to imply merely a background knowledge of technical information, supplementary to the facts acquired in classroom and laboratory; they are meant to include also a comprehension of the values of technical literature, the ability to interpret these values from varying viewpoints—technical, professional, literary, economic—, and the power of putting literary knowledge to work for actual technical accomplishment. The student who has an adequate knowledge of source material, types of publications, and authorities in the literature of his special field; who can evaluate and abstract, as he reads and studies existing literature, who makes intelligent records of the knowledge he gains from reading; who reads widely, thinks about what he reads, and correlates specific subjects into a comprehensive whole—is well started on the road to success.

Increasing familiarity with engineering literature builds up a fund of knowledge concerning the profession itself. The student reads the publications of professional engineering societies and learns of their aims and accomplishments, the work of their committees, the trends of engineering interests and responsibilities. He begins to visualize ideals for his own future accomplishment. An idea, conceived perhaps in a moment of interesting laboratory experimentation, may grow through reading and thought into a prize paper presented as a student member before a professional society meeting. Further growth of the idea into a thesis may draw the attention of a future employer.

Likewise with vocational information. Through colloquia, special lectures, and employment interviews the student meets possible employers and learns their requirements and interests. Through their publications he learns about the actual organizations, the industrial and commercial companies, the public utility corporations, of which he may become an employee.

Librarian as Guide

The engineering librarian is in a strategic position for aiding in the solution of these student problems. To the idea of the librarian as source of information should be added the thought of the librarian as guide, interpreter, and coördinator. The librarian, constantly studying the literature of the field, sees the complete picture, the whole academic course, the whole profession, with all their ramifications. Not responsible for teaching the technical details of any one specific course subject, the librarian can help the student bring together the lines of knowledge from all his courses into a connected network. Not responsible for any scholastic grading, the librarian has exceptional opportunities for studying individual traits and orientation problems, for encouraging ambition or relieving discouragement. In addition to the collecting of source materials and new publications, and the preparation of best facilities for their use, the librarian should interpret and teach the values of engineering literature, study student reader personalities, meet individual reading needs, and show how the spirit of research in reading always leads to breadth of professional knowledge.

Engineering educators are stressing also the need of post-academic education with a program continuing after college graduation. They interpret the undergraduate curriculum as training the student to become an engineer, showing him the possibilities of self development; while post-graduate courses in industry emphasize the balance between study and accomplishment, the theoretical plus the practical, and the need for continuation of some

study throughout life. With the scope and range of engineering constantly growing, only through libraries can the adequate record of its progress be kept; only through use of engineering libraries can engineers keep in complete touch with professional developments. Library habits acquired as undergraduates assure the success of later independent study.

Engineering School Library of the Future

What of the future engineering school library?

The engineering school library should be administered for active coöperation in the educational plan of the department which it serves. The librarian should be trained in library techniques and educational methods, and should possess a scholarly interest in following the developments of the specialized engineering field. Instruction in technical library usage, given a definite place in the engineering curriculum, should be integrated with previous general library instruction. Prescribed lectures on library usage and engineering literature should be arranged in a progressive course according to the needs of departmental instruction. Diagnostic tests of library aptitudes should be used to detect individual student needs. Such tests would be particularly helpful in the case of transfer and graduate students. The inclusion of a certain amount of standardized instruction in the fundamentals of engineering library usage in all engineering school curricula would make the change from one library to another merely a matter of orientation. In addition to the prescribed library lectures a short optional course in advanced bibliographic research should be available, particularly for doctorate candidates, but open also to any others interested.

In physical arrangement the engineering school library should be planned with reference to the very differing needs of underclassmen and upper-classmen. For the latter, some scheme of departmentalization according to the various fields of engineering should provide adequate space for the service of a special reference librarian, individual study cubicles for student reading, and seminar rooms for group discussion.

The days when an engineering education could be secured from the study of a few textbooks are over. Engineering students face a constantly widening field of knowledge with a literature of infinite extent. Engineering school libraries must grow correspondingly. Their future development will tend doubtless toward specialization in certain schools, with concentration in large centers of technical research. New techniques of bibliographic research are developing rapidly. Microfilm copies are already common in the interlibrary lending of reference material, and their use requires

a new technique of reading and adaptation. Mechanical selectors are being developed to produce at a moment's notice hundreds of references from the card files of large research libraries. Future engineers must keep abreast of all such developments, and librarians must train engineering students in the adequate handling of the ever-increasing masses of technical literature. Library research techniques are becoming increasingly important in the process of engineering education. The engineering librarian must become more and more a coöperating teacher. The engineering library must live up to the progressive standards of the profession which it serves.

UNIVERSITY OF ILLINOIS HONORS ARTHUR NEWELL TALBOT

The Arthur Newell Talbot Laboratory will be the new name for the present Materials Testing Laboratory after a convocation ceremony on April 21, 1938, at the University of Illinois. Already the recipient of the highest awards conferred by the societies of his professional interests, Doctor Talbot will now be uniquely honored by his Alma Mater for those brilliantly active years as a teacher and an investigator which have contributed so much to the University of Illinois and to the engineering profession.

Robert Ernest Doherty, Illinois '09, President of the Carnegie Institute of Technology, Pittsburgh, Pa., will make the principal address at the afternoon ceremony to be held in the university's newly remodeled auditorium. A banquet and reception to be held in the evening of the same day will bring the celebration to a close.

The University of Illinois is publishing a booklet entitled, "A Tribute to Arthur Newell Talbot," commemorating the renaming of the laboratory. The booklet is being sent to a large number of friends of Doctor Talbot and the University of Illinois. A limited number will be available upon application to Professor F. E. Richart, College of Engineering, Urbana, Illinois.

PHYSICS, MATHEMATICS, AND ENGINEERING

By FRED. E. AYER

Dean, College of Engineering, University of Akron

The following study is interesting in that it shows the correlation between ability in physics and mathematics, and capacity for engineering training. Inasmuch as engineering is applied physics, and an understanding of its laws requires time as well as study, we have always required physics as both a freshman and a sophomore subject for engineers.

The study includes the freshmen who entered in September from 1921 to 1931 inclusive, and the graduates who received their degrees in June of the years 1926 to 1936 inclusive, ours being a five-year coöperative course. The grades are for the first semester and no account is taken of the relatively few who may have entered in mid-year, or who transferred from other departments or other colleges.

Freshmen entering in September	745	
Graduated in Engineering	207	or 27.8%
Failed neither mathematics nor physics	469	
Graduated in Engineering	185	or 39.5%
Failed mathematics and passed physics	116	
Graduated in Engineering	17	or 14.7%
Failed mathematics, or mathematics and physics	230	
Graduated in Engineering	20	or 8.7%
Failed either or both	276	
Graduated in Engineering	22	or 8%
Failed physics and passed mathematics	46	
Graduated in Engineering	2	or 4.3%
Failed physics and mathematics	114	
Graduated in Engineering	3	or 2.6%

Our conclusion is that engineering students who can not, or will not, pass mathematics and physics in their first semester, better transfer to some other department.

NEW MEMBERS

ALBERT, ODD, Assistant Professor of Structural Engineering, Newark College of Engineering, Newark, N. J. H. N. Cummings, R. W. Van Houten.

BARNES, JOHN L., Assistant Professor of Mathematics, Tufts College, Tufts College, Mass. R. H. Frazier, E. H. Wright.

BRIDGER, JOHN C., Assistant Professor of Civil Engineering, Mississippi State College, State College, Miss. D. M. McCain, H. C. Simrall.

DORNBERGER, W. W., Assistant Professor of Architecture; Assistant Supervising Architect, University of Texas, Austin, Texas. P. M. Ferguson, J. W. Ramsay.

ENEY, WM. J., Instructor in Civil Engineering, Lehigh University, Bethlehem, Pa. S. A. Becker, C. D. Jensen.

FISHER, DAVID A., Instructor in Mechanical Engineering, College of the City of New York, New York City. F. Kuhlen, G. J. Bischof.

HARRISON, EARNEST R., Instructor in Mechanical Engineering, Georgia School of Technology, Atlanta, Ga. R. S. Sweigert, W. V. Dunkin.

HUNTLY, PHIL C., Professor of Mechanical Engineering and Director of Option, Armour Institute of Technology, Chicago, Ill. H. T. Heald, S. E. Winston.

MERRYFIELD, FRED, Associate Professor of Civil Engineering, Oregon State College, Corvallis, Ore. C. A. Mockmore, W. H. Martin.

REID, ERNEST A., Associate Professor of Electrical Engineering, University of Illinois, Urbana, Ill. M. A. Faucett, H. N. Hayward.

RICHTMANN, WILLIAM M., Associate Professor of Mechanical Engineering, Texas College of Arts & Industries, Kingsville, Texas. R. L. Peurifoy, F. L. Bishop.

SCHULZ, ELMER H., Instructor in Electrical Engineering, University of Texas, Austin, Texas. J. W. Ramsay, H. E. Degler.

SCOATES, DANIELS, Professor of Agricultural Engineering, A. & M. College of Texas, College Station, Texas. Re-admission.

SLAYMAKER, R. R., Associate Professor of Machine Design, Case School of Applied Science, Cleveland, Ohio. Re-admission.

SMITH, ELMER G., Assistant Professor of Physics, A. & M. College of Texas, College Station, Texas. N. F. Rode, M. C. Hughes.

STOKER, JAMES J., Assistant Professor of Mathematics, New York University, New York City. S. K. Barrett, F. L. Bishop.

UPDEGROVE, HENRY T., JR., Instructor in Mechanical Engineering, College of the City of New York, New York City. F. Kuhlen, G. J. Bischof.

296 individual members elected since July 1, 1937.

CIVIL ENGINEERING PAGE

HAROLD C. BIRD, *Chairman* — PAUL P. RICE, *Secretary*
H. E. BABBITT — HALE SUTHERLAND
F. T. MAVIS — H. T. HEALD

SUMMER CONFERENCE ON STRUCTURAL PRACTICE

L. E. GRINTER
Dean, Graduate Division, Armour Institute of Technology

At a meeting of the directors of the Civil Engineering Division in New York in January it was decided to sponsor a Summer Conference on Structural Practice to be held in Chicago June 20–24, 1938. This Summer Conference has been approved by the parent society and has been accepted for joint sponorship by the Armour Institute of Technology.

The Summer Conference on Structural Practice was planned for the summer of 1937 but was postponed until 1938 to avoid conflict with the Surveying Summer School of 1937. About thirty pre-registrations were sent to the writer last year which is a clear indication of the general interest in structural practice among civil engineering teachers. It is confidently assumed that the attendance at the conference on structural practice this year will be from all parts of the country and will represent all ranks of civil engineering teachers from instructors to department heads and deans. It is an interesting fact that the pre-registrants last year were about equally divided between the younger instructors and the older and more experienced teachers and administrators.

The plan for a summer conference this year embodies a coöperative arrangement with the structural industry in the Chicago area. It is thought that the conference can be subdivided into four parts, one part to be discussed each day: (1) Standards of Drafting and Detailing where some of the tendencies toward a revision of standards can be settled, (2) Fabrication, Welding, and Shop Procedures which will cover these subjects for the teacher without shop experience or with no recent experience in the shop, (3) Construction or Erection Methods which should acquaint us with the new developments in the art and (4) Cost Estimating, a study that is entering the civil engineering curriculum through devious means. The plan is further for each of these main divisions to be handled by the best qualified engineers from a selected structural company. These engineers will be encouraged to arrange a program that will involve the greatest possible service to the teacher with the least expenditure of time. Some may plan an actual inspection of working methods along with lectures and demonstrations.

The time is set for June 20–24, with the following arrangement in mind. The four days, Monday, June 20 to Thursday, June 24, will be devoted to the four divisions mentioned above. The conference will be adjourned Thursday afternoon so that the members can drive to College Station, Texas, where the annual S. P. E. E. meeting will convene for the first civil engineering session on Monday, June 27. This will allow the members a full three days to drive the thousand miles between these two meeting places. Slow drivers will be able to leave the conference in Chicago on Thursday noon, June 24, without missing the main discussions of the Conference on Structural Practice.

Teachers interested in structural practice should address either the writer or Mr. Clayton O. Dohrenwend of the Armour Institute of Technology, Chicago, and indicate their interests. Mr. Dohrenwend will arrange for convenient and economical housing for guests. Costs of operating the Conference will be kept to a minimum and it is thought that the cost per person may be only a dollar or two to cover possible mailing of programs and mimeographing of papers for distribution at the meeting. A central meeting place will be designated at a later date for preregistration on Saturday, June 18, and Sunday, June 19, so that guests may arrange their hotel or other accommodations with the aid of Mr. Dohrenwend before the beginning of the Conference.

ENGINEERING ECONOMY PAGE

Engineering Economy is the phase of engineering work in which technical plans and operations meet the critical and constructive test of applied economics.

EDMUND D. AYRES, University of Wisconsin, *Editor*

ENGINEERING ECONOMY IS ENGINEERING

As to the scope of the term "Engineering Economy," please chalk up another vote in favor of limiting it to matters which are distinctly of an engineering nature.

To cite a familiar case—if we are designing an engine, the question "how efficient can we make it?" must be coupled with the question "how efficient can we afford to make it?" For the latter we must give consideration to the effect on manufacturing and installation costs; to the probable effect on fuel costs, maintenance, and other items of operation throughout the life of the machine; to the interest factor by which we weigh future costs and present costs in the same balance; to the degree of certainty or uncertainty with which these future conditions can be foreseen. And if the project involves discarding an old machine which might be still used, we must take special care not to deceive ourselves about it.

So it goes in the performance of engineering projects of all sorts, if we keep our eyes open. River and harbor improvements—bridge, tunnel and highway construction—electric distribution system extension—automobile and airplane design—each project presents its own set of problems in applied economics, not only in judging the desirability of the project as a whole, but also in shaping its various parts. The technical matters involved force this field of action into the hands of engineers. "Engineering Economy" is an apt name for it.

To orient engineering students for work of this sort, we, of course, want them to have a sound grasp of general economics and a vital understanding of human affairs. But is it desirable to include general social and cultural studies under the banner of "Engineering Economy"? I think not; for after all, the engineers' needs in these fields are about the same as the basic needs of all who aspire to good citizenship and constructive leadership. We would not want a narrow presentation of them in the classroom.

Or is it desirable to include studies of industrial management methods, personnel administration, and the like? Personally I would as soon try to teach the principles of musical harmony to a man who had never heard music, as to offer subject matter of that sort to a student who had not spent considerable time in industry.

If we confine the use of the term "Engineering Economy" to that field of applied economics which inevitably falls to the lot of the engineer, then perhaps we may better emphasize this aspect of the engineer's responsibility to society.

LAURANCE E. FROST,
Consolidated Edison Company of New York, Inc.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FRED W. SLANTZ, EDITOR

NATIONAL DRAWING COMPETITION, 1937–1938

Auspices of the Division of Engineering Drawing and Descriptive Geometry, Society for the Promotion of Engineering Education.

Chairman, PROFESSOR A. W. LEIGHTON, Engineering School, Tufts College, Mass.

SUMMARY OF THE GENERAL REGULATIONS

1. The competition is limited to first year students without professional experience.

2. An Engineering Drawing Department may submit one drawing only in each of the nine different classes of problems.

3. Each submitted drawing must be accompanied by a statement covering complete identification of the student and a record of his instruction.

4. The problems and special specifications will be furnished schools desiring to enter contestants by the Chairman, A. W. Leighton, Tufts College.

THE PROBLEM CLASSES

Class AP.—Required: A pencil drawing made with instruments embodying orthographic shape description. Choice and treatment of views, as well as execution are a part of the problem.

Class AT.—Same as Class AP except that a pencil tracing (accompanied by the pencil drawing) is required.

Class AI.—Same as Class AP except that an inked tracing (accompanied by the pencil drawing) is required.

Class BP.—Same as Class AP except, required: A pencil drawing made with instruments, including both an orthographic shape description and size specifications. Choice and treatment of views, execution, dimensioning, etc., are part of the problem.

Class BT.—Same as Class BP except that a pencil tracing (accompanied by the pencil drawing) is required.

Class BI.—Same as Class BP except that an inked tracing (accompanied by the pencil drawing) is required.

Class C.—Required: A complete working (shop) drawing submitted in the form of an inked tracing accompanied by the pencil drawing. Choice and treatment of views, dimensioning, etc., are a part of the problem.

Class D.—Required: A freehand pictorial sketch. Choice of position, method of representation, execution, etc., are a part of the problem.

Class E.—Required: Lettering in pencil and lettering in ink from written copy. Arrangement, form and proportion of letters, execution, etc., are a part of the problem.

JUDGING

First and second places will be awarded in each class except that no awards will be made for any class in which there are not at least five entries.

Theory, practice, technique, and student judgment shall constitute the basis for judging all drawings.

The judges shall be three in number selected by the Chairman of the Division of Engineering Drawing. The Chairman of the National Competition Committee shall be, ex-officio, a non-voting member of the judging committee.

The problems and special specifications which supplement the general regulations will be ready for distribution to all institutions deserving to enter the competition, at any time after April 1, 1938.

This year an entrance fee of fifty cents is being required of each institution entering the Competition, the purpose of which is to cover extra postage and materials required for the instructions and also for the return of exhibits and the preparation of the awards to the winners.

Editor's Note: Provision for reduced reproductions of the winning drawings in the *Journal of Engineering Drawing* and/or a traveling exhibit of these drawings among the schools entering the competition should be arranged.

ENGLISH NOTES

DEVOTED TO THE INTERESTS OF TEACHERS
OF ENGLISH IN ENGINEERING SCHOOLS

J. L. VAUGHAN, *Editor*

MEMORANDUM ON PLACE OF THE TEACHING OF ENGLISH IN ENGINEERING EDUCATION

Because the engineering school provides the entire program of education for its students beyond the secondary school level, it has the obligation of providing the elements of a liberal education as well as of a professional training. In this connection the term "liberal" should not be defined narrowly. The following statement is proposed as a means of orienting consideration of the place of English in a properly balanced program of education for engineers:

"A liberal education is one that will aid the individual in acquiring a clear conception of the environment, social and physical, in which he lives, the origins from which it has sprung, and the evolutionary process through which it has reached its present state, to the end that he may live in it a useful and happy life."

In this statement, the words *social, useful* and *happy* have the following connotations: *Social* is intended to include not only what is thought of as societal or sociological, but also what is commonly termed cultural. By *useful* is implied productive, which requires vocational proficiency. It also is intended to comprise civic usefulness, including specifically the intelligent exercise of the right of suffrage. The term *happy* is used in a broad sense to include the understanding, appreciation and enjoyment of the world outside of one's vocation and one's family.

In an educational program intended to serve such broad purposes as those implied in this statement, it is clear that instruction in the use of the mother tongue must occupy a place of major importance. Seriously to neglect it, or to provide instruction of a quality other than of the highest obtainable order of excellence, would be to defeat a major purpose of a properly conceived program of engineering education.

It is clear also that provision for the study of English in an engineering curriculum should comprise all of its three principal

subdivisions: composition, literature and speech. The first of these is usually assumed and provision made for it. In too many instances the latter two are omitted or slighted. It would seem to be axiomatic that few will learn to write with clarity or distinction who do not read great writers. It is also clear that in the brief and crowded college years, there will not be sufficient opportunity to do more than lay foundations or to point the direction to subsequent attainment. In the study of English this must mean the development of a taste and inclination for reading. Courses in literature for engineering students should have as a major purpose the serving of this end.

Of the staff groups comprising an engineering faculty, two occupy key positions in relation to the non-scientific, non-technological portion of the curriculum: those of Economics and of English. The latter especially occupy a most strategic place with respect to the broader aspects of the education of engineers. It is the function of the staff of this department to develop clarity of thinking as prerequisite to clarity of expression. It is the opportunity and the responsibility of this staff to develop the literate, educated men that the fundamental position of engineering requires in modern society.

H. P. Hammond.

SECTIONS AND BRANCHES

The sixth annual meeting of the **Pacific Southwest Section** was held on the campus of the Los Angeles Junior College, December 28–30, 1937, with an attendance of approximately seventy. The members were welcomed by Roscoe C. Ingalls, Director of the Junior College. The following papers and discussions were presented at the general meetings of the Section:

"General Engineering," by Professor Thomas T. Eyre, University of Southern California.

"What Industry Expects of the Engineering Graduate," by C. T. Reid, Assistant Chief Draftsman, Douglas Aircraft Corporation. Discussion by Professor Boynton M. Green, Stanford University.

"Counselling the Technically Inclined Student," by Archie M. Turrell, Pasadena Junior College.

"Teaching of Hydraulics," by Professor R. L. Daugherty, California Institute of Technology. Discussion by Professor Morrough P. O'Brien, University of California.

"Engineering Education from the Viewpoint of the Practicing Engineer," by Mr. Arthur G. Atkinson, Structural Engineer with the San Francisco Bay Exposition Company.

"Laws of Learning," a continuation of his paper of the preceding year, by Professor L. M. K. Boelter, University of California. Discussion by Professor R. R. G. Watt, University of Southern California.

"The Unit Principle of Laboratory Instruction," by Professor Willard P. Berggren, University of California. Discussion by Professor Sydney F. Duncan, University of Southern California.

"Report of the Committee on Relationships between Junior and Senior Colleges," by Professor Harry B. Walker, University of California, Chairman.

"Progress Report on Curriculum Accrediting," by Dean G. M. Butler, University of Arizona. Discussion by Professor Jay A. Carpenter, of the University of Nevada.

The afternoon of the first day was devoted, as an experiment, to three separate conferences, on civil, electrical and mechanical engineering. The following papers were presented at these conferences:

Civil Engineering:

Lecture Courses, by Professor Robert M. Fox, University of Southern California.

Design Courses, by Professor Franklin Thomas, California Institute of Technology.

Laboratory Courses, by Professor E. C. Flynn, University of Santa Clara.

Mechanical Engineering:

Lecture Courses, by Dean George L. Sullivan, University of Santa Clara.

Design Courses, by Professor W. Howard Clapp, California Institute of Technology.

Laboratory Courses, by Dean F. H. Sibley, University of Nevada.

Electrical Engineering:

Lecture Courses, by Professor Ernest F. Peterson, University of Santa Clara.

Design Courses, by Professor Abe Tilles, University of California.

Laboratory Courses, by Professor I. J. Sandorf, University of Nevada.

These papers were followed by lively informal discussion. In view, however, of the general interest in the subjects covered and of the size of the Section, it was voted not to divide the Section into separate conferences at future meetings. Professor Thomas and Dean Sibley were, unfortunately, prevented by illness from being present and delivering their papers in person.

The ladies were entertained at tea the first afternoon of the meeting in Pasadena, at the residence of Mr. and Mrs. Leon W. Holman, of the host institution. That evening, the members and ladies visited the Griffith Planetarium, which overlooks the city from the hills behind Hollywood. There they saw a fascinating reproduction of the motions, past, present and future, of the heavenly bodies and listened to a most entertaining lecture by Professor Clemenshaw, of the Planetarium and of the University of Southern California.

On the following afternoon, two inspection trips were made; one to Station "B," of the Bureau of Power and Light, where the Boulder Dam power is received in Los Angeles, and one to the Morris Dam of the Metropolitan Water District and Dam No. 1 of the Los Angeles County Flood Control works in San Gabriel Canyon. In the evening, the members and ladies were guests at an informal dinner at one of the Los Angeles restaurants. As speaker of the evening, Dean Samuel B. Morris, Stanford Uni-

versity, gave a very interesting discussion of water resources planning.

The invitation of the University of Santa Clara, for the seventh annual meeting of the Section to be held at that institution in December, 1938, was accepted.

The following officers were elected for the year 1938:

Chairman: George L. Sullivan, University of Santa Clara.
Vice-Chairman: Jay A. Carpenter, University of Nevada.
Secretary-Treasurer: Franklin O. Rose, University of Southern California.
Additional Members of the Executive Committee: John W. Hazen, Los Angeles Junior College; Boynton M. Green, Stanford University; James C. Clark, University of Arizona.

FRANKLIN O. ROSE,
Secretary-Treasurer.

NECROLOGY

Joseph A. Thaler, Head of the Electrical Engineering Department at Montana State College, died March 11, 1938.

Professor Thaler was born in Kitzbuhel, Austria, November 29, 1864, and came to this country in 1886. Shortly thereafter he joined the 6th U. S. Infantry. After his discharge from the Army in 1892, he moved to Minneapolis. Aiding college students in making reports, while working for a transit company, gave him a desire to acquire a college education. In 1900 he was graduated from the University of Minnesota. Professor Thaler taught at the University of Minnesota and Purdue before assuming the headship at Montana State College where he taught for 35 years.

Professor Thaler was a Fellow in the A. I. E. E.; a member of the S. P. E. E. since 1901 and was a member of Council in 1906–09.

BOOK REVIEWS

Elementary Surveying, Vol. 1, seventh edition. CHARLES B. BREED AND GEORGE L. HOSMER. John Wiley and Sons, Inc.

From casual inspection it would seem that the latest edition of Breed and Hosmer's Elementary Surveying contains the same number of pages as the previous editions. Such is not the case, the new edition contains quite a number of additional pages, these pages carrying a printed letter subscript. Referring from one addition to another is simplified, chapter XI, as an illustration, continues to start on page 389.

The most important change to this reviewer is the fact that the number of problems has been materially increased. Chapter 1, probably used by all classes in surveying, now contains twenty problems, some of which can be subdivided into additional problems. This compared to the ten problems in older additions makes the chapter more flexible in regard to problem assignments. So far as noticed all problems at the end of chapters have been expanded accordingly.

Some new material has been added to the reading matter.

The logarithmic tables continue to be to five places.

W. IRWIN SHORT.

Transient Electric Currents. HUGH HILDRETH SKILLING. McGraw-Hill Co., Inc. 349 pages. $4.50.

Transient phenomena occur in an electrical system every time a switch is closed or opened, when the load on a motor is changed, or in case of any alteration of resistance, inductance, or other constant of a circuit while it is carrying current. This transient electrical condition may be accompanied by a transient mechanical disturbance. Such disturbances endanger power system stability and involve tremendous surges of energy that may endure for several seconds.

"Transient Electric Currents" by Hugh Hildreth Skilling is certain to find favor with anyone concerned with the study and calculation of transient phenomena. Students and instructors will be pleased with the clear straight forward style and the efficient and lucid mathematical treatment. Mathematics is neither avoided nor over-emphasized and all mathematical development is com-

plete in every detail. Many problems are included at the end of each chapter. A desirable feature of these problems is the inclusion of full page oscillograms of the problem circuits. If laboratory facilities are available students may use their own oscillograms, if not those included in the book may be used. This feature will be attractive to those wishing to teach themselves the fundamentals of transient calculation.

"Transient Electric Currents" contains ten chapters.

I. The Behavior of Inductance—4 problems.
II. The Behavior of Condensers—6 problems.
III. The Circuit Equations—3 problems.
IV. The Complete Single Circuit—7 problems.
V. Networks—8 problems.
VI. Response to Alternating Voltage—6 problems.
VII. Coupled Resonant Circuits—3 problems.
VIII. Circuits With Variable Parameters—7 problems.
IX. Traveling Waves—9 problems.
X. Operational Method of Analysis.

A brief but useful course may be given by covering the first five chapters. After the first six chapters any chapter may be included or omitted at the discretion of the instructor.

JAMES A. WASMUND.

Business Administration for Engineers. C. FRANCIS HARDING AND DONALD T. CANFIELD. McGraw-Hill Book Company, Inc. 637 pages. $5.00.

"The engineer as the business executive of the future" may be a trite slogan, as stated in the preface, but—it remains a fact nevertheless. As a result almost every engineering curriculum contains at least one course devoted to teaching the fundamentals of business, legal and ethical relationships. We are beginning to appreciate more and more the importance of the presentation of this material from the engineering point of view—and by engineers.

After a brief introduction the following general subjects are treated: Business Organizations; Property Values; Financing the Corporation; Accounting for the Finances; Return on the Capital; and Public Service Corporations.

The arrangement of the material and selection of problems makes this not only a good text book but a handy reference volume for the practicing engineer.

H. E. DYCHE.

Low Temperature Physics. M. AND B. RUHEMANN, Physico-Technical Institute, Kharkhov. Cambridge University Press, 313 pages, price $5.00, The Macmillan Company.

In this book, the authors "discuss the principal problems that have occupied low temperature physicists since the time when low temperatures began to form a separate branch of experimental science." They have treated rather sparsely matters such as supra-conductivity and specific heats, which are treated elsewhere, while other matters such as crystal structures stable at low temperatures, have been treated fully. They have, so they say, "taken pains to avoid the rigidity and professionalism of a textbook."

The book is divided into four parts which are headed, 1, Phase Equilibrium, 2, The Solid State, 3, Orbit and Spin, and 4, the Free Electron. Parts 1 and 2, particularly the former, should be of great interest to the industrial physicist and the low temperature engineer. In what way this is so will appear from the titles of the chapters: Part I, Early Methods of Gas Liquefaction; Industrial Air Liquefaction; The Production of Low Temperatures; the Measurement of Low Temperatures; Rectification in Theory and Practice; Solid Liquid Equilibrium. Part II, The Crystal Lattice; The Thermal Energy of Crystals; and Nernst's Third Law. Frequent and excellent use has been made of entropy-temperature and other similar diagrams with generally only a slight use of mathematical devices. In the reviewer's opinion, these chapters are excellently written and readily understandable.

In parts 3 and 4, there is more of an appeal to the physicist who is concerned with principles rather than applications. The chapter titles are: Part III, Internal Degrees of Freedom; Paramagnetism; and Magnetic Cooling. Part IV, Conductivity at Low Temperatures and Supra-Conductivity. Regarding the field of low temperature physics, to which the authors have made important contributions, they say, "Our efforts to draw nearer to zero are not merely the hectic desires of a record-hunter but are dictated by a genuine curiosity as to the properties of matter. . . . Half a century's experience has taught us that as long as we are in a position to attain yet lower temperatures, there will always be something of interest to study there, even if it is but those processes with the help of which the temperature has been lowered. No one seriously believes that because five-thousandths of a degree is the lowest limit hitherto reached, there is no point in attempting to go farther." Therein they show the true spirit of the physicist.

If, however, regarding the quest for the absolute zero, one asks what is the use, let him study the subdivisions on The Melting Curves of Condensed Gases and note how, from the study of

helium and other liquids at obtainable pressures and temperatures, one may, on the basis of corresponding states, make reasonable deductions regarding the probable behaviors of other substances in the fields of pressures and temperatures which thus far have been unattainable.

To the reviewer there are certain features of the book which cause some annoyance as he reads and particularly as he refers occasionally to one part or another of the book for definite information. They are the tendencies 1, to leave out essential details in the legends to the figures and tables; 2, to specify quantities without due regard to the preciseness of their units; and 3, to omit the unit when specifying a quantity. On page 20, there is shown an "Inversion curve of Joule-Thomson effect"; but, for what or in what units T and P are expressed has to be searched out by him who in quest for related material comes upon it, or by him who, from a desire to refresh his memory regarding the subject, returns to it. Another illustration occurs on pages 153 to 158 where molal heats in consecutive figures are expressed in terms of cal/°, cal/mole, cal/°K, cal/°K mole and in one case in no units whatever.

Despite some of these features which cause annoyance and some actual uncertainty now and then, the book as a whole appeals to the reviewer as one that is highly interesting and valuable for the field of low temperature physics. Further, it is readable and generally comprehensible for those who find joy in the non-mathematical treatment of our frontiers.

A. G. WORTHING.

G-E *Campus News*

FOR OUTSTANDING ACHIEVEMENT

EACH year General Electric honors those employees who have done outstanding work in their fields as provided in the Charles A. Coffin Foundation. This year 40 men were chosen—15 of them college graduates:

Adelbert Alexay, Polytechnic Institute of Budapest, '11; *Alexander Babillis, Rose Polytechnic Institute, '28; *T. M. Berry, Kansas State College, '27; Michael Broverman, Tri-State College, '22; F. E. Carlson, University of Michigan, '25; *S. B. Crary, Michigan State College, '27; R. E. Farnham, Case School of Applied Science, '17; J. W. Gilchrest, Cooper Union, '08; *A. H. Lauder, University of Wyoming, '22; *Domenico Martignone, Central Technical College of London, '01; *F. N. Neal, University of Utah, '31; *D. R. Shoults, University of Idaho, '25; F. C. Smith, Drexel Institute, '06; *L. A. Umansky, Polytechnical Institute of Petrograd, '15; R. E. Worstell, Purdue University, '25.

If any one generalization could be made to cover the qualifications for this award, it would probably hinge upon the extent to which an employee took advantage of his opportunities, beyond the ordinary routine of his work to achieve an outstandingly worth-while result.

Former G-E Test man

LIGHTNING GUIDER

AFTER three years of photographing natural lightning striking the Empire State building in New York City, it was determined that many lightning strokes which appear to crash from the clouds to the ground actually are met part way by a small flash, originating from the earth, which guides the stroke to its destination.

In addition, laboratory tests, under the direction of Karl B. McEachron, graduate of Purdue University and former G-E Test man, indicate that discharges between points and planes always begin at the point. The Empire State represents to the cloud a tremendous needle on the earth's surface. Thus the guiding flash will originate from the tower and shoot upward.

Destruction occurs when a lightning bolt contacts a high-resistance area. Lightning conductors prevent this by grounding the discharge in an area of low ground resistance and the lightning control on the Empire State affords a protective area within a radius of approximately one mile.

GENERAL ELECTRIC

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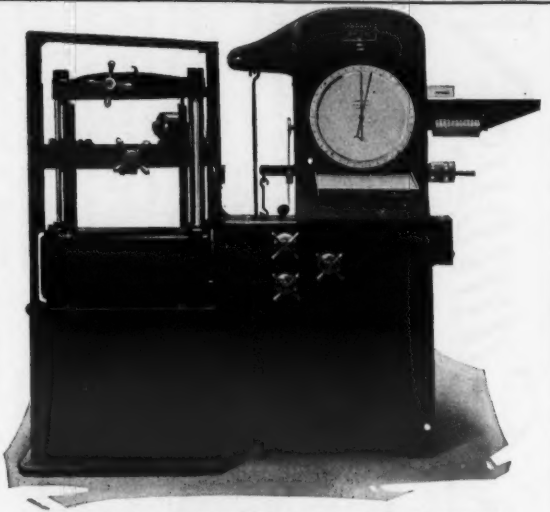

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